The use of supply chains and supply chain management to improve the efficiency and effectiveness of GIS units

by

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THESIS

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Declaration

I declare that this thesis is my own original work, conducted under the supervision of Dr Lukas Scheepers and Prof. Piet de Wit. It is submitted for the degree of Doctor of Philosophy in the Faculty of Science at the University of Johannesburg, Johannesburg. No part of this research has been submitted in the past, or is being submitted, for a degree or examination at any other university.

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In memory of my father, Günter Schmitz

Dedicated to my wife, Ellena
and to my mother, Elke Schmitz

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List of Abbreviations

3PL	Third-party logistics
AFIS	Advanced Fire Information System
AGD	Australian Geodetic Datum
AM/FM	Automated Mapping and Facilities Management
AMPS	All Media and Product Survey
APEC	Asia-Pacific Economic Cooperation
APICS	American Production and Inventory Control
APP	Aggregated Production Plan
BOM	Bill of Materials
CBU	Completely built-up
CGIS	Canada Geographic Information System
CKD	Completely knocked-down
COO	Certificate of origin
CPFR	Collaborative planning, forecasting and replenishment
CSIR	Council for Scientific and Industrial Research (South Africa)
DBSA	Development Bank of Southern Africa
DEM	Digital Elevation Model
DIME	Dual Independent Map Encoding
DME	Department of Minerals and Energy
DRP	Distribution Resource Planning
DTM	Digital Terrain Model
ECR	Efficient Consumer Response
EDI	Electronic Data Interchange
EFT	Electronic Funds Transfer
EIA	Environmental Impact Assessment
EOQ	Economic Order Quantity
ERD	Entity Relationship Diagram
ERDAS	Earth Resources Data Analysis Systems
ERID	Eskom Research and Innovation Department
ERP	Enterprise Resource Planning
ESI-GIS	Electricity Supply Industry Geographical Information System
ESRI	Environmental Systems Research Institute

EU	European Union
FGDC	Federal Geographic Data Committee
GDA	Geocentric Datum of Australia
GIRAS	Geographical Information Retrieval and Analysis System
GIS	Geographic Information System
GML	Geographic Mark-up Language
GPS	Global Positioning System
HELP	Housing and Electrification Load Programme
IARC	Industry Association Resource Centre
IDP	Integrated Development Plan
IMRID	Information Manipulation on a Grid
INEP	Integrated National Electrification Programme
IOR-ARC	Indian Ocean Rim Association for Regional Cooperation
ISO	International Organization for Standardization
IT	Information technology
JIT	Just-in-time
LBS	Location-based services
LIS	Land information system
LTL	Less-than-truck load
MDB	Municipal Demarcation Board
MPC	Multi-purpose Cadastre
MPLIS	Multi-Purpose Land Information System
MPS	Master Production Schedule
MRO	Maintenance, repair or overhaul
MRP	Materials Requirement Planning
NRE	Natural Resources and the Environment, CSIR
OGC	The Open GIS Consortium
PC	Personal Computer
PDA	Personal Digital Assistant
PIOS	Polygon Information Overlay System
POS	Point-of-sale
QR	Quick Response
RCCP	Rough-cut Capacity Plan
RDD	Research and Development Department of Eskom

RED	Regional Electricity Distribution
RFP	Request for Proposal
RRP	Resource Requirement Planning
SAA	South African Airways
SAARF	South African Advertising Research Foundation
SABS	South African Bureau of Standards
SAC	Satellite Applications Centre, CSIR
SADC	Southern African Development Community
SAGDaD	South African Geospatial Data Dictionary
SANS	South African National Standard
SASDI	South African Spatial Data Infrastructure
SAUID	South African unique identifier
SCOR	Supply-Chain Operations Reference model
SDTS	Spatial Data Transfer Standard
SQL	Standard Query Language
StatsSA	Statistics South Africa
SWOT	Strength, Weaknesses, Opportunities and Threats
TIGER	Topologically Integrated Geographic Encoding and Referencing
TL	Truck load
TQM	Total Quality Management
UML	Unified Modelling Language
UNS	User Needs Study
UPC	Universal Product Codes
URISA	Urban and Regional Information Systems Association
USGS	United States Geological Survey
VMI	Vendor-managed Inventories
WfMC	Workflow Management Coalition
WOODSS	WOrkflOw-based Spatial Decision Support System
WTO	World Trade Organisation

Chapter 1: Introduction and Methodology

1.1 Introduction

Dangermond (1999) and Tomlinson (2000) both provide a view on the future of Geographic Information Systems (GIS) in the 21st century. Society will become more spatially enabled, meaning that geography and GIS will become embedded in mainstream decision-making and incorporated into enterprise systems such as Oracle and SAP (Dangermond, 1999; Hughes, 1999; Sonnen, 2000; Tomlinson, 2000; and Mann as interviewed by GEO World, 2004[1]). With the above in mind, both Dangermond (1999) and Tomlinson (2000) indicate that the emphasis in GIS has moved away from research on the various applications of GIS, data collection methodology and analytical procedures to research and development on how to model complex spatial systems such as the built environment, to predict outcomes for decision-making as well as to understand these complex systems and outcomes. Dangermond (1999) also mentions that the large spatial databases that are needed for the abovementioned activities will lead towards *"a kind of geographic accounting system or geoaccounting"* (Dangermond, 1999:3). Furthermore, Dangermond (1999) indicates that geography is the foundation upon which the above discussion is built and that geology, oceanography and sociology, to name a few disciplines, also have geographic elements even if they are only used to describe the area of study and where the samples have been collected. These geographic elements contain geographic information that can be used by a GIS for mapping and geospatial analysis.

The availability of these different large spatial databases, as well as the rapid improvement in information and communication systems such as broadband, open networks and the interoperability between various operating platforms and software and back office systems, will lead to challenges such as security, access to data, data quality, ethical issues and archival policies (Dangermond,

[1] GEO Europe and GEO World provide at the end of each year an industry outlook for the next year by interviewing industry leaders and noted academics in GIS and publishing their views in the last issue of that particular year.

1999 and Tomlinson, 2000). Both authors indicate that these challenges can be best addressed through proper management. Based on the above discussions, Dangermond (1999) and Tomlinson (2000) indicate that those Geographic Information System (GIS) units or organisations that are able to manage themselves successfully will reap the benefits regarding the products which they offer to their customers. Tomlinson (2000:3) further indicates that *"the new millennium will see greatly improved GIS management tools"* to enable a GIS unit or organisation to provide these identified products. In the context of this study, the term **GIS unit** is used for both a GIS unit (a unit within an organisation) and a GIS organisation (an independent entity that provides products to its customers using GIS). Pulsani, interviewed by GEO World (2004:7), further indicates that there is a need to access and/or disseminate "*the right data at the right time and in the right format*" in order to be effective and competitive.

The objective of this study is to provide such a "tool", namely the establishment of supply chains and supply chain management to manage this chain, enabling a GIS unit to respond to the needs of their customers with the right product at the right time in an efficient and effective manner. This "tool" will enable a GIS unit to manage its data from its sources (suppliers), during creation of the product at the GIS unit and delivery of the product to the GIS unit's customers.

Supply chains and supply chain management are mostly studied in the field of logistics. However, since GIS is seen as a sub-discipline of geography, which in turn resides in most instances within the scope of the natural sciences (and combined with the need mentioned above by Dangermond (1999) and Tomlinson (2000)), it was decided that the use of supply chains and supply chain management as an alternative management model for GIS units could be researched in this discipline. This decision is further supported by the fact that various publications within the ambit of GIS on the management of GIS, including the use of workflow, have been published, such as those of Obermeyer and Pinto (1994), Huxhold and Levinsohn (1995) and Coleman (2004). It is thus possible that this research could contribute to the current knowledge of managing GIS units. Furthermore, supply chains and supply chain management themselves have elements of geography, namely the location of suppliers, warehouses, manufacturing plants, distribution centres and customers and the distance between these entities. These locations and distances have an effect on the supply chain with regard to the costs of transport the goods between these entities as well as the time required to move these goods. One of the steps when using the Supply-Chain Operations Reference (SCOR) Model is to map these locations and assign the various applicable management categories to each of these locations (Supply-Chain Council, 2005). Thus GIS and geography can in turn also be used in supply chain management to aid in the improvement of the supply chain. A further result of this research could be that supply chain management can be used as a management model for research in other aspects of geography and in the natural sciences. This is because here data and resources need to be sourced from various sources, and used by multiple researchers on or in support of the same project or various research projects and disseminated to other researchers or institutions that form part of the research consortium. The use of GIS will ensure that the right data or resources are accessed or disseminated at the right time and in the right format. Resources can range from researchers, support personnel, hardware and software to laboratory equipment. Thus this research could be beneficial to GIS, geography and natural sciences. To place this research in the context of GIS, it is necessary to give a brief overview of the development of GIS over the last 40 or more years.

The term Geographic Information System (GIS) was coined in the 1960s when the Canada Geographic Information System (CGIS) was developed (Longley *et al.*, 1999) in response to the Canadian government's need for a land inventory system (Foresman, 1998). Since then GIS has developed, and in the 1990s it became increasingly accessible to businesses as a tool for analysis and forecasting.

With the rapid development of GIS, it became necessary to manage GIS from its implementation into an organisation to GIS projects themselves. Cassettari (1993), Huxhold and Levinsohn (1995), Somers (1996 and 1998) and Sugarbaker (1999) approach the management of a GIS in a holistic sense starting with the placement of GIS in an organisational context with respect to the GIS itself, the reasoning behind its use, what it is and what it can do for the organisation to achieve its strategy and goals (Cassettari, 1993 and Huxhold and Levinsohn, 1995). From this viewpoint the data issues with respect to the type of data that need to be collected (spatial and non-spatial), data models, database design and management (Cassettari, 1993 and Huxhold and Levinsohn, 1995 and Sugarbaker, 1999) are determined. Other aspects that are looked at are the technological setting of the GIS, the type of GIS, such as low-end or high-end GIS, and the supporting information technology infrastructure to carry such a GIS project (Cassettari, 1993 and Huxhold and Levinsohn, 1995).

Other management issues discussed which are in support of the above are implementation planning and management (Huxhold and Levinsohn, 1995), the system design methodology employed to design the GIS (Huxhold and Levinsohn, 1995 and Reeve, 1998), which can include the analysis of functionalities and the customisation of the GIS (Cassettari, 1993). The latter looks at the user-GIS interface (Cassettari, 1993). Sugarbaker (1999) also indicates the importance of managing customer and operations support for the GIS as well as project and workload planning.

Seffino *et al.* (1999) and Li and Coleman (2004) use workflow modelling to manage and track GIS projects as well as to automate certain functions within GIS projects. According to the Workflow Management Coalition (WfMC, 1998 as quoted in Li and Coleman, 2004:4) *workflow* is defined as ‘the automation of business processes during which documents and tasks are passed among participants according to a set of procedural rules and assigned roles. Business processes according to the WfMC are those linked sets of procedures and activities that are put in place to achieve the organisation’s strategic objectives (Li and Coleman, 2004). Seffino *et al.* (1999) use scientific workflow for their spatial decision support system, which was developed to manage and execute scientific experiments and procedures such as DNA testing. The advantage of using workflow is to manage distributed GIS data productions (Li and Coleman, 2004). Seffino *et al.* (1999) use workflow to manage spatial decision-support for agri-environmental planning activities.

Based on the above methods on managing GIS and GIS projects, the management is done either on a holistic level, which ranges from determining the need for a GIS to the implementation of the GIS in an organisation, or on a task level where workflows are used to track and manage GIS projects. The aim of this PhD research, combined with the comments made by Dangermond (1999) and Tomlinson (2000) as mentioned in the first paragraph, is to propose and demonstrate **supply chain management,** which lies between these two approaches of planning and managing GIS products. Supply chain management in the manufacturing industry looks at the flow of materials from different suppliers to a manufacturing unit that creates the product through to the delivery of the final product to the client at the other end of the chain, as well as the flow of information and money between them (Handfield and Nichols, 1999, and Roberts, 2003). Supply chain management also looks at the holding of inventory and completed products at warehouses and distribution centres. Warehouses and/or distribution centres can be situated between the supplier and manufacturer or at the manufacturer and the client (Roberts, 2003).

A similar concept was mooted by Reeve (1998), who drew an analogy between the motor industry and a GIS product. He used the term "value chain analysis" to analyse the sequence of processes to create a product, but limited it to the concept of improving the chain by improving the information technology of an organisation. The result of any GIS project is a product or a service; in this research, the term **GIS product** is used in this context. Supply chain management of GIS products looks at the flow of data (spatial and non-spatial) from suppliers to the GIS unit, the conversion or transformation of the data into a product by the GIS unit and the delivery of the GIS product to the client at the other end of the supply chain. Supply chain management also examines the flow of information and money between the entities of the supply chain, such as the placement of an order for the GIS product or the payment for data from the suppliers. It also suggests that some of the management aspects of the holistic approach could be used to support the supply chain. An example would be database management. Similarly, workflows can be used to automate certain parts of the supply chain such as the acquisition of data or the processes involved to complete a specific GIS product. A supply chain can be described as follows:

> *"The supply chain encompasses all activities associated with the flow and transformation of goods from the raw materials stage (extraction), through to the end user, as well as the associated information flows. Material and information flow both up and down the supply chain"* (Handfield and Nichols, 1999:2).

Based on the brief discussions above as well as on the definition by Handfield and Nichols, the definition of a supply chain in the GIS field can be formulated as follows:

> ***"The supply chains encompass all activities associated with the flow and transformation of spatial and attribute data from the raw data stage (capturing), through to the end user, as well as the associated information and money flows. Data, information and money flow up and down the supply chain."***

Capturing, in this context, encompasses all data capturing processes, whether capturing data using a digitising tablet, field work using a Global Positioning System (GPS) tool to capture coordinates, or data captured using remote sensing platforms. Remote sensing platforms can be either optical (for example satellite imagery) or those that create their own radiation such as radar and lidar.

This section has discussed very briefly the two existing approaches of managing GIS and GIS products, namely the holistic and workflow approach. These two approaches do not regard the total supply chain as a whole for managing the GIS and GIS products from the source through to the client, and it is suggested that supply chain management be used to manage this chain. The next section gives a brief overview of GIS in organisations and the management of GIS as well as its shortcomings and the role of supply chain management.

1.2 Geographic Information Systems in organisations

Geographic Information Systems (GIS) were developed from the outset to assist organisations to manage information. The first such development occurred in the 1950s. Although not a fully-fledged GIS, it was used to analyse agricultural data. The data were captured on a computer which did the analysis, and the results were then hand-mapped onto maps (Longley *et al.*, 1999). This development laid the foundation for the creation of the first official GIS, the Canada Geographic Information System (CGIS) as mentioned in Section 1.1. The development of GIS from the 1960s to the present can be grouped into five stages, which are given below:

- The first stage, or the pioneering age, started in the 1960s and lasted through to 1975. It was dominated by laying of the foundations for GIS.
- The second stage according to Foresman (1998) was the research and development age. During this phase, further developments were made in the GIS field which were built on the ground-breaking work carried out during the first phase.
- The commercialisation of GIS, where GIS became entrenched in organisations as a tool to assist them to analyse and manage spatial data for a variety of uses, ranging from facilities management and land inventories, through to applications in environmental issues. During this phase, several GIS systems were made commercially available and several firms, institutions and public sectors implemented GIS as a tool to provide services. Some of these were successful, and some were not so successful. GIS also became entrenched in academia, which led to the establishment of the National Centre for Geographic Information and Analysis at the University of California in the late 1980s (Foresman, 1998). According to Obermeyer and Pinto (1994) as well as Huxhold and Levinsohn (1995) management issues were not addressed during this phase although the need for management started to arise as GIS was increasingly implemented in organisations. The need for management of GIS became increasingly vital during the next phase, which was dominated by the users of GIS.

- The users of GIS dominated this phase (from the late 1980s onwards) and the vendors were reacting to the clients' needs and organising user conferences to exchange ideas, experiences and applications. It is during this phase where management issues are given attention, which has led to the publication of books and articles such as those by Blackmore (1991), Obermeyer and Pinto (1994), Huxhold and Levinsohn (1995), Somers (1996 and 1998) and Sugarbaker (1999). Several papers dealing with management aspects were also presented at the 2004 ESRI User Conference that investigated the holistic approach to the management of GIS (Harrison, 2004a; Moy, 2004 and Gadish, 2004). All these articles discuss management issues at the holistic level. Although comprehensive, they address only parts of the supply chain and not the complete supply chain
- With the establishment of the Internet as a general-purpose tool to access information on any topic anywhere in the world, as well as the development of intranets, mostly in big corporations, it is the most logical thing that geographic information will be, and is currently being, distributed over the Internet and via intranets, either as spatial data in map form (static or interactive), or by allowing the user to access GIS functionality remotely, ranging from simple spatial activities such as distance calculations to complex spatial modelling and analysis (Tang and Selwood, 2003). This is known as distributed geographic information (DGI) applications (Plewe, 1997) or GIS Web services (Tang and Selwood, 2003). An example is the Geography Network, which provides a Web-based catalogue of Internet services, spatial data provision, maps or GIS functionalities. *"The Geography Network conforms to the Web services concepts of Publish, Find, and Use* (Tang and Selwood, 2003:13)*"*. Figure 1.1 illustrates the Geography Network concept. The Geography Network has been developed by ESRI to provide access to a huge amount of data. SA-ISIS is a South African service or GIS brokerage based similar principles. The interesting part is that SA-ISIS is not software specific, whereas the Geography Network needs ESRI products to view the data (Tang and Selwood, 2003 and Tucker, 2003). Li and Coleman

(2004) use the above capabilities for distributed spatial data production and employ workflow procedures to manage these projects.

In the previous sections, the evolution of GIS up to the present was discussed. The following sections discuss information obtained from magazines and journals in the geotechnology arena which gives an indication of industry trends and innovations. Geotechnology is a term used to describe the different GIS software and related technical and software products such as global positioning systems (GPS), surveying equipment, digital aerial photograph cameras and software to capture data using GPS and personal digital assistants (PDA). The aim of this section is to strengthen the motivation for the use of supply chain management to plan and manage GIS products.

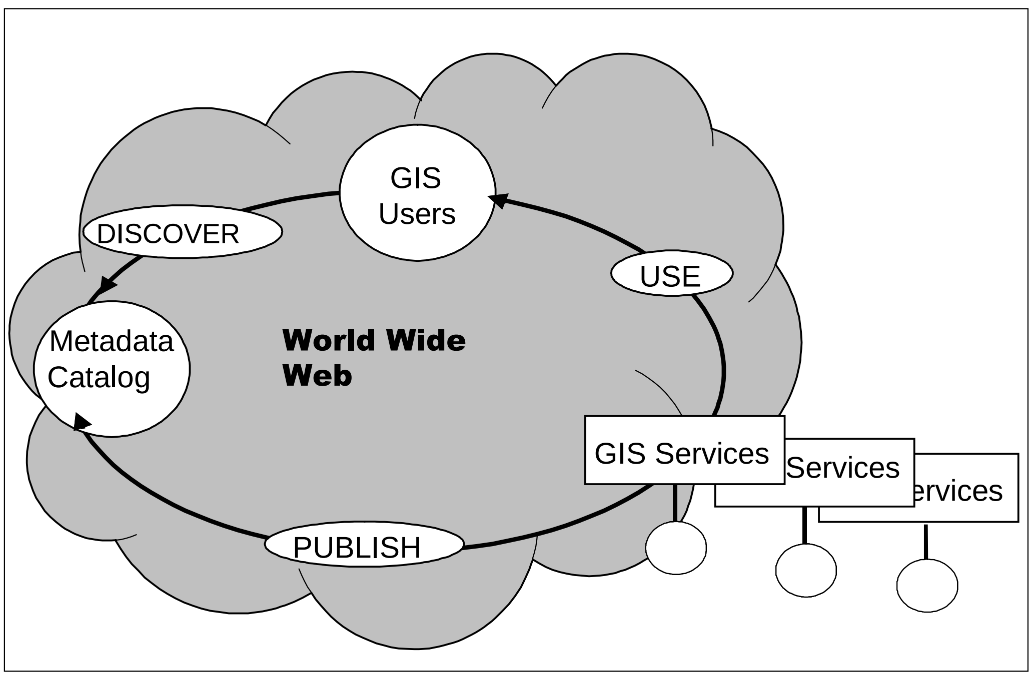

Figure 1.1: The Geography Network

(from Tang and Selwood, 2003, figure on p 13)

According to the literature, GIS is increasingly becoming part of organisations' mainstream information technology systems, allowing it to move from the desktop to the mainstream architecture where the spatial data can be used by several entities within the organisation as part of their daily routine (Hughes, 1999; Holsmüller as interviewed by GEO Europe, 2000; Batty, 2003; Benson, 2004; Farley, 2004; and Maguire as interviewed by GEO World, 2004). This allows the GIS to be integrated with the organisation's mainstream technology systems, which include Enterprise Resource Planning systems such as SAP or PeopleSoft, or enterprise database management systems such as Oracle, IBM or Informix, which make provision for the management and storage of spatial data as part of their flagship products (Hughes, 1999; Sonnen, 2000; Limere as interviewed by GEO World, 2003; and Mann as interviewed by GEO World, 2004).

The rapid improvement in hardware, information systems infrastructure, Web services (enabling applications to share data irrespective of the operating systems on which these applications run) and bandwidth allows for advanced spatial modelling and predictive analysis, drawing spatial and non-spatial data directly from an enterprise data warehouse as well as from outsourced data providers. This enables an enterprise to acquire a better understanding of its consumer market and consumer behaviour as well as the location of its customer base, which will in turn improve its competitive edge (Moon as interviewed by GEO World, 2003; and Drinnan as interviewed by GEO World, 2004).

Outsourcing of non-core spatial data activities is done to save costs, and enterprises that outsource normally then concentrate only on their core spatial data assets. Enterprises that provide outsourced services take the responsibility and risk for these spatial data sets (Drinnan as interviewed by GEO World, 2004). If an enterprise starts to outsource its non-core spatial activities, the management of the outsourced products and the processes involved as well as the flow of information between the customer and supplier become critical, and that entails a new kind of management approach (Drinnan as interviewed by GEO World, 2004). Supply chain management in the manufacturing environment such as the automotive or textile industry has been successfully implemented to manage the outside enterprises to which the non-core activities are outsourced (Christopher, 1998).

A location-based service, which is a service that uses a person's location, to provide that person, e.g. via cellular telephone, with points of interest within a specific distance of his or her location, or where a person can request a specific point of interest such as an automatic teller machine, places a huge demand on up-to-date locational data (points of interest) as well as the ability to deal with real-time receiving and dispatching of spatial data (Batty, 2003; and Lombardi as interviewed by GEO World, 2004). Vodacom's (a cellular service provider in South Africa) location-based service is called Look4it, and the spatial data are outsourced to a company (AfriGIS) that specialises in spatial data products and services. The company also provides the locational data to a person requesting information after Vodacom has patched the location of the person through to AfriGIS (Abouchabki, 2005 and Rademeyer, 2005). Another use of location-based services is the tracking and management of assets, which has its own spatial data management requirements (Lombardi as interviewed by GEO World, 2004). Supply chain management could be used to improve location-based services, especially managing the currency of locational data that may be sourced form different data suppliers.

Another reason for the use of supply chain management is the move of the Geographic Information System (GIS) community towards open and interoperable systems. This move is very strongly championed by the Open Geospatial Consortium, which also lays down the standards and specifications of interoperable and open systems to which most of the big role-players in the GIS community belong as consortium members (Lutz as interviewed by GEO World, 2004). The application of open and interoperable systems enables users to access overwhelming amounts of spatial and non-spatial data, and the challenge, as mentioned in Section 1.1, is to access and/or disseminate the right data at the right time and in the right format. This phrase is very similar to the phrase in the manufacturing industry where companies employ logistics processes that include all "*the firms that are involved in ensuring that the customer gets the* right *product, at the* right *time, in the* right *condition and in the correct quantities*" (Roberts, 2003: SCM 101-Unit 1 p 4). This process, where all the suppliers, manufacturers and customers, as well as the firms involved in moving and warehousing the products, is known as the supply chain. Managing and coordinating this chain is known as supply chain management (Roberts, 2003).

This section discussed the directions in which the geotechnology industry is moving, and it is clear that the quantity of data that can be accessed and/or disseminated will increase more and more over time. It has been noted that accessing these huge volumes of data is much easier and quicker than before, which led to Pulsani's statement quoted in Section 1.1. These movements in the industry require a new approach, namely regarding all the involved parties as a supply chain using supply chain management to manage the supply chain.

Because it evolves over time, the overriding issue is that a GIS needs data, with its associated metadata, which is stored, manipulated and displayed to give answers. These data sets need to be managed to ensure data integrity and currency. Vert *et al.* (2002a and 2002b developed software to manage a wide variety of GIS data; it into different sets based on similarities obtained from the metadata from the data files. This approach allows for the management of GIS data in various formats such as ArcGIS, Erdas, GeoMedia as well as in raster and vector formats within one set. This management approach improves only the way GIS data are managed, and not the whole process involved in sourcing, creating and distributing GIS data. The next section gives an overview of supply chains and supply chain management and how supply chains and supply chain management can be used in GIS.

1.3 Supply chains and supply chain management

This section gives an overview of supply chains and supply chain management. A short history and some definitions of supply chains and supply chain management are given. At the end of this section the link between GIS and supply chains and supply chain management are demonstrated using definitions of GIS and a hypothetical GIS supply chain.

According to Christopher (1998), wars were won through good logistics and lost through bad logistics. The need for good logistics has been common knowledge in defence forces for centuries, but it is only very recently that commercial enterprises have discovered the value of logistics to give them a competitive advantage. Shaw, in 1915, wrote (as referenced by Christopher, 1998) about the importance of integrated logistics, which coordinate activities amongst different role-players involved in supplying, manufacturing and distributing products.

Forester, in 1958 (as referenced by Mentzer *et al.*, 2001), mentioned that after a period of research, progressive managers will realise that their companies' well-being is dependent on relationships, an understanding of the different functions within the company and the relationship of the company with its external environment such as its market place, customers, etc. Forester then developed a computer program to simulate changes through the system.

Mentzer *et al.* (2001) indicated that the "Beer Game" simulation and the "Bullwhip Effect" had been developed from the work of Forester. From the late 1980s and early 1990s supply chains and supply chain management became "the topic" in the business world. The driver for supply chains and supply chain management is to assist the firm in providing the customer with the "right" product, at the "right" time, in the "right" condition and the "right" amount as ordered by the customer (Roberts, 2003).

According to Christopher (1998), logistics provide the platform to plan for the flow of product(s) and information through a company and supply chain management looks at achieving linkages and coordination between the processes of the other entities involved in the product which flows through the company. These entities are the suppliers and the customers.

Owing to the rise in popularity of supply chains and supply chain management, the Supply-Chain Council (www.supply-chain.org) was established in 1996 as a not-for-profit organisation. The members of the council consisted of people from big corporations such as Bayer, Compaq, Procter & Gamble and Lockheed Martin, to name a few, who are knowledgeable in supply chains and supply chain management. The aim of the council was to establish an industry standard model for supply chain implementation. The model is known as the Supply-Chain

Operations Reference Model (SCOR) (Bolstorff and Rosenbaum, 2003). The SCOR model will be used to model and manage the GIS unit's supply chain. Figure 1.2 gives a schematic overview of the SCOR model.

SCOR breaks up the supply chain for modelling purposes into five categories, namely:

- PLAN – assessing and planning the supply chain.
- SOURCE – all the activities involved in sourcing the materials to manufacture the product.
- MAKE – all the activities involved in making the product.
- DELIVER – all the activities involved in delivering the finished product either to a warehouse, distribution centre or the customer.
- RETURN – which deals with processes involved when goods are returned to the company (Bolstorff and Rosenbaum, 2003).

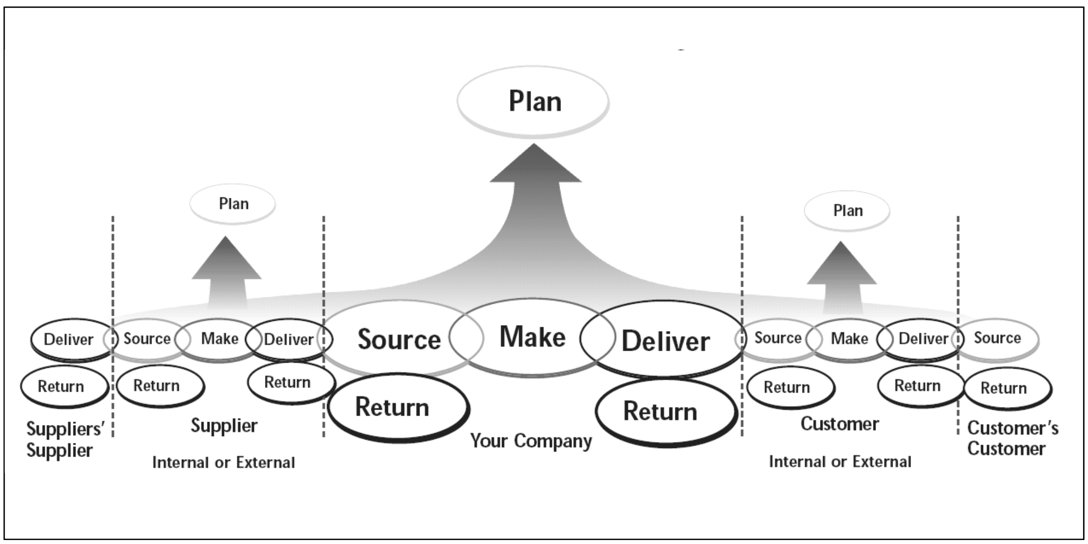

Figure 1.2: The SCOR model

(from Supply-Chain Council, 2005:3)

These five management categories are derived from the definition of a supply chain as given in Section 1.1. Mentzer *et al.* (2001) indicate that a minimum number of three members is required to form a supply chain, namely the supplier, the manufacturer and the customer. Mentzer *et al.* (2001) termed this chain the **basic supply chain** (see Figure 1.3).

According to De Kok and Graves (2003) there are a myriad of definitions defining supply chain management, some of them even in conflict, thus making it necessary to use the following two definitions:

> "Supply chain management (SCM) *is the integration of these activities through improved supply chain relationships, to achieve a sustainable competitive advantage* (Handfield and Nichols, 1999:2)."
>
> or:
>
> "*The management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole* (Christopher, 1998:18)."

Supply chain management embraces strategic, tactical and operational management issues that will provide the company and the supply chain members with a competitive advantage over its competitors (De Kok and Graves, 2003). Upstream suppliers are those firms that supply material to the manufacturer, whereas the downstream customers are those firms that receive the finished product from the manufacturer (Handfield and Nichols, 1999). From a GIS point of view the upstream suppliers provide spatial and non-spatial data to the GIS unit, whereas the downstream customers receive the GIS product from the GIS unit. According to Mentzer *et al.* (2001) the following two types of supply chains in addition to the basic supply chain mentioned above are identified (see Figure 1.3).

- The **extended supply chain,** which looks at the supplier's supplier, the supplier, the firm, the customer and the customer's customer. These are also the basic building blocks used by the Supply-Chain Council's Supply-Chain Operations Reference model (SCOR) (Supply-Chain Council, 2003). This is also similar to Handfield and Nichols' (1999) idea of the integrated supply chain model (see Figure 1.4).

- The **ultimate supply chain**, which consists of all the suppliers and customers at all levels, the firm as well as third-party logistics companies, and all relevant information moving up and down the chain.

Figure 1.3 illustrates these three types of supply chain. The extended supply chain format is used to model a GIS unit's supply chain owing to the usage of the SCOR model for this PhD research.

The previous few paragraphs have examined the definitions, concepts and types of supply chains. Firms use supply chains and supply chain management to streamline their manufacturing processes as well as to enhance their competitiveness and improved profitability (Nix, 2001 and Roberts, 2003). According to Roberts (2003), three basic commodities flow through a supply chain amongst the members, namely: (i) products; (ii) information; and (iii) cash. Products flow from the supplier to the ultimate customer, and there is also some reverse flow of products owing to various factors such as faulty products, products that are past their sell-by date or where used products are collected either to be recycled or disposed of in a controlled manner (Roberts, 2003 and Supply-Chain Council, 2003).

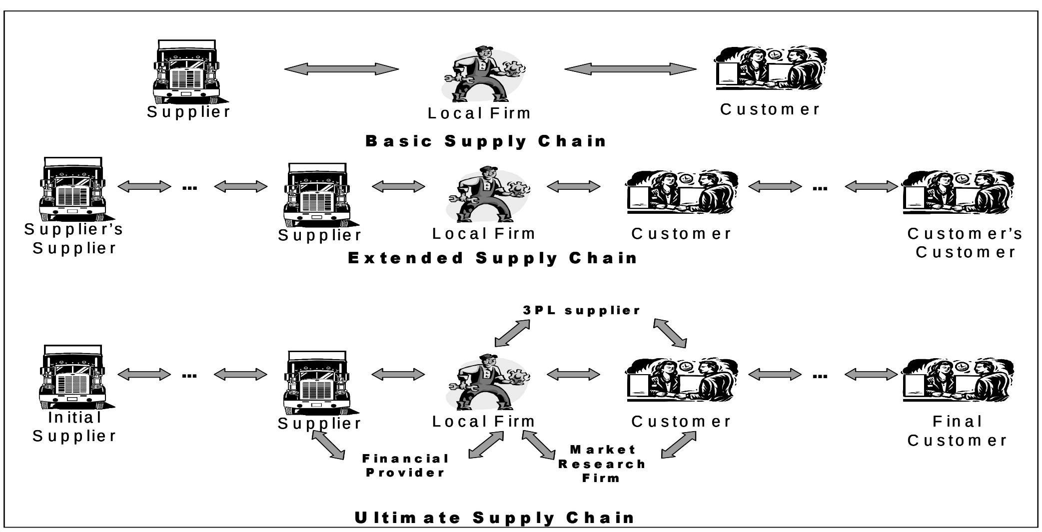

Figure 1.3: The three different types of supply chain

(from: Mentzer *et al.*, 2001:7, Figure 1.1)

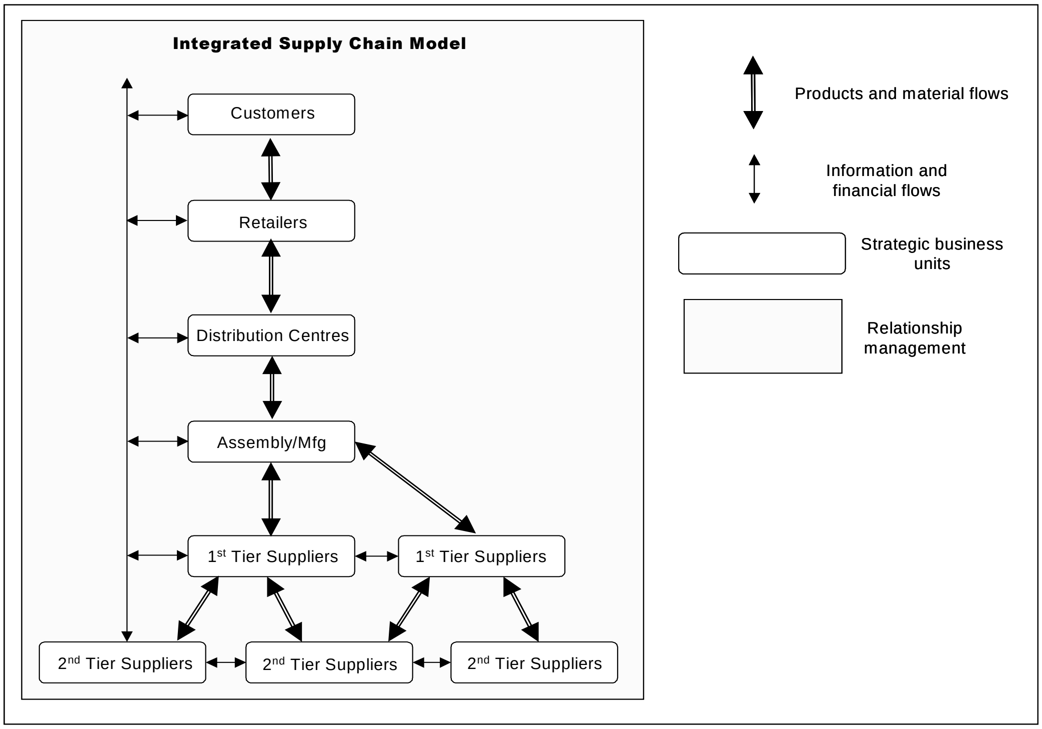

Figure 1.4: Integrated supply chain
(from: Handfield and Nichols, 1999:5, Figure 1-3)

The reduction of inventory through the supply chain is one of the aims, if not the aim, of supply chain management, and the only way to do this is to keep the supply chain as visible as possible. The use and flow of information in a supply chain is one of the critical factors for keeping the visibility. A key issue is trust amongst the supply chain members, which allows for sharing of company-sensitive information (Christopher, 1998; Handfield and Nichols, 1999; and Roberts, 2003). Table 1.1 gives the key factors and characteristics of a supply chain.

Table 1.1: The key factors and characteristics of a supply chain

Factor	**Characteristic**
Inventory management	Pipeline coordination amongst the members of the chain
Inventory flows	Must be seamless and visible along the pipeline
Cost	The landed cost of goods must be minimised
Information	Information must be shared amongst the members to create an improved supply chain
Risk	The risk of the whole chain is shared amongst the members of the supply chain

Planning	Planning is done using a supply chain team approach
Inter-organisational relationships	Partnerships focused on landed cost

(from: Roberts, 2003, SCM 101-Unit 1: Supply Chain Management, Table 1. *Supply Chain Management Certificate Program: Course notes*)

Successful moulding of the factors in Table 1.1 into an integrated supply chain is based on the following three objectives (Roberts, 2003: SCM 101-Unit 1: Supply Chain Management, p9):

- "*Recognising the final customer's service level requirements;*
- *"Deciding where to position inventories along the supply chain and how much to stock at each point;*
- *"Developing appropriate policies and procedures for managing the supply chain as a single entity*."

Reduction in time can be achieved by using, for example, cross-docking (very short inventory holding time) or just-in-time (JIT) procedures where the inventory arrives at the plant at the time when it is needed. VMI (vendor managed inventories), where the vendor is responsible for having stock available when the customer needs it, is an example of an inventory reduction procedure.

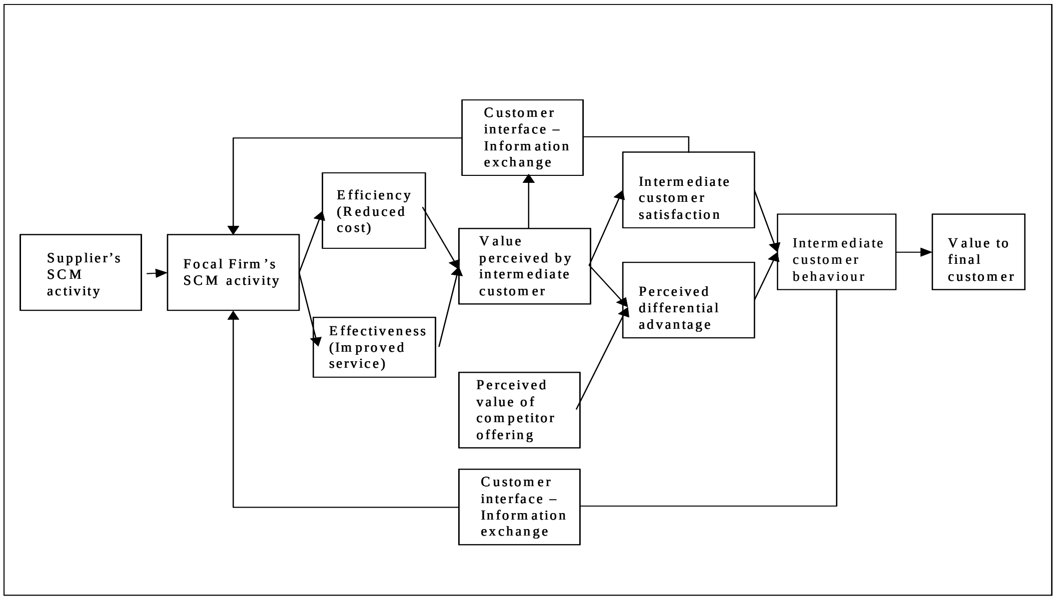

Figure 1.5: Consequences of supply chain management

(from: Nix, 2001: *The Consequences of Supply Chain Management,* p 64)

Third party logistics (3PL) alliances, which provide a full logistics service ranging from transport, warehousing to information service provision and result in firms concentrating their efforts at producing the products and services as required by the customer, can be used as examples by firms in the supply chain as strategies to improve the supply chain (Roberts, 2003). Figure 1.5 above gives a diagrammatic view of the results for a firm implementing a successful supply chain management.

This section has given an overview of supply chains and supply chain management as well as the consequences of a well functioning supply chain. The next section examines how supply chains and supply chain management can be used in the GIS arena, based on the fact that the definitions of a GIS already contain elements of a supply chain.

1.4 Supply chains and GIS

The term Geographic Information Systems (GIS) for purpose of this research is defined as follows:

> *A GIS is a* ***computer-assisted system****, combined with appropriate* ***infrastructures, resources and management****, that* ***acquires, stores, retrieves, transforms, manipulates*** *and* ***displays geographical and related non-geographical data****.*

To be able to run any type of GIS application:

- The data need to be sourced from various suppliers (acquire).
- The sourced data need to be manipulated by the GIS to find answers for the application (store, retrieve, transform and manipulate), which is a GIS product.
- The GIS product is delivered to a client, where the client will display the product after its acquisition.

The sourcing, storing (which resembles inventory and/or warehousing) and manipulating of data (spatial and non-spatial) as well as delivering the GIS product indicates a typical supply chain, which necessitates supply chain management to ensure the effective use of GIS, especially in a large organisational or institutional set-up or if a large amount of different data sets are utilised. e-Land is an example of the latter, which uses 135 different layers to assist the Gauteng provincial government in its decision-making process when identifying suitable land for low-cost housing developments (e-Land, 2004). One of the biggest management issues facing e-Land and is to keep these 135 data layers current.

The definition of a GIS has been discussed in the above paragraphs to illustrate how a GIS, according to its definition and application, contains the components of a supply chain, namely: sourcing, manipulation and delivering, and that supply chain management may be used to manage GIS products. The next few paragraphs examine a hypothetical supply chain for a GIS unit based on the above discussions.

Figure 1.6 illustrates a hypothetical GIS supply chain. This supply chain can be applied to small or large GIS projects. A client requests a specific GIS product from the manufacturer ("The Firm"). Information starts to flow from the client to The Firm when either an order via fax, e-mail or the Internet arrives at The Firm. The Firm then searches the warehouse, which would be a data warehouse, to establish whether the GIS product is available or not. If available, the GIS product is sourced from the warehouse and delivered to the client via an FTP site from which the client can download the GIS product onto CD-Rom, hard disc, etc. The delivery mechanism is the logistics of how to distribute the GIS product, and infrastructure is part of the distribution planning. "The Knowledge Factory" and the "Chief Directorate: Surveys and Mapping" are examples of firms which warehouse GIS products that are immediately available to clients, and they publish catalogues of what is available.

When the GIS product is not available in the warehouse, it has to be manufactured by The Firm. The GIS Unit, which is the manufacturing arm of The

Firm, then plans the GIS product and sends information to interrogate the inventory for stored data sets. Some of the data sets needed for the GIS product are held in inventory, and the rest of the required data must be sourced, either in-house or from outside suppliers. The sourcing request is sent out to the suppliers (in-house or outside) and the suppliers deliver their data sets. The Firm keeps them in inventory until they are needed to manufacture the GIS product.

This part is known as production planning and inventory control. Once the GIS product has been completed, The Firm delivers it to the client via the warehouse as described above.

This section has illustrated a hypothetical supply chain for a GIS product showing the flow of data from the supplier to the GIS unit, which transforms it into a product and delivers it to the client. It has also shown the flow of information and money between the different entities. Thus, a GIS product produced by a GIS unit can be managed using supply chain management.

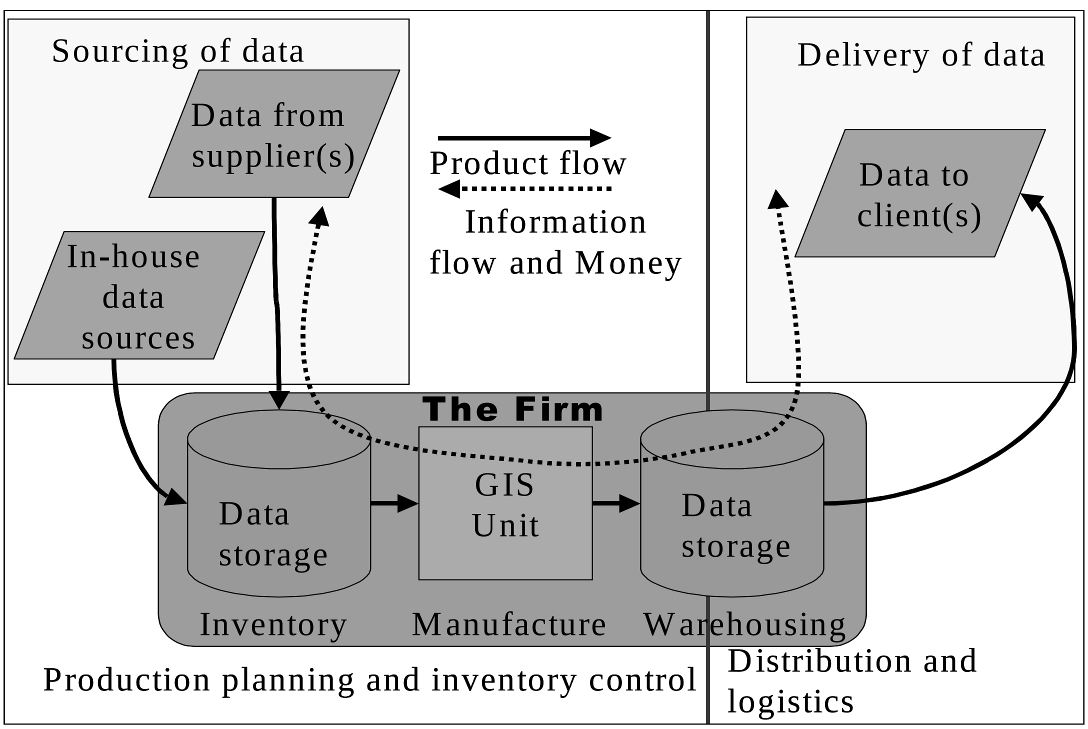

Figure 1.6: Hypothetical GIS supply chain

(based on Beamon, 1998: *The Supply Chain Process*, Figure 1)

1.5 The research objective

Section 1.2 examined the evolution of GIS over time as well as GIS management that is done either at a holistic level or at project level. The other management aspect discussed briefly is the management of the wide variety of GIS data used by a GIS unit. It was also shown that these approaches, although valid in every aspect, do not address the management of the production of the various GIS products produced by a GIS unit. In Section 1.3 supply chains and supply chain management are discussed with the aim of linking them to the definitions of a GIS to illustrate that the definition of a GIS does intrinsically describe a supply chain as illustrated in Section 1.4. To illustrate this concept in more detail, a hypothetical GIS supply chain has been discussed in Section 1.4. It is also argued that these different management approaches can be used to support the supply chain at various levels.

The research aim for this study is as follows:

> ***Can the establishment of supply chains and the utilisation of supply chain management assist a GIS unit to be more efficient and effective in the use of GIS when creating and delivering a GIS product?***

In order to achieve the above research aim, the following objectives need to be realised:

A. **What are supply chains and supply chain management?**
   To realise this objective, supply chains and supply chain management need to be investigated that were developed for the manufacturing industry such as the automotive and pharmaceutical industries, where physical products are moved through a supply chain from the raw material stage through to the delivery of the finished product to the final client. A thorough understanding of supply chains and supply chain management is necessary in order to establish whether it can be used as an alternative management model to manage GIS. This has been briefly discussed in Section 1.3.

B. What is GIS and where it is applied?

To determine whether the establishment of supply chains and the management of these supply chains can be applied to GIS it necessary to examine the nature of GIS and where it is applied, as discussed briefly in Section 1.2.

C. How is GIS currently managed in GIS units?

It is necessary to consider the various management practices currently in use of managing a GIS unit. Section 1.2 gave an overview on the current management of GIS units.

D. Can supply chain management be linked to GIS in order to become a management tool for GIS?

Objectives A, B and C discussed supply chains and supply chain management, GIS and current GIS management practices respectively. Based on the outcomes of these three objectives, this objective seeks to answer whether it is possible to use supply chains and supply chain management in the context of GIS as illustrated in a few words in Section 1.4.

E. Can supply chain management be used to successfully manage the production of GIS products by a selected GIS (ESI-GIS)?

To realise this objective it is necessary to investigate the following:

- The nature of the GIS unit, namely ESI-GIS, that will be used as a case study.
- The establishment of supply chains in and the application of supply chain management to ESI-GIS.

The scientific relevance of this research is to demonstrate the use of supply chains and supply chain management to improve the efficiency and effectiveness of a GIS unit. This research investigates in detail the processes involved and the flow of spatial data and the related attribute data from the source, and the manipulation of the data through to the delivery of the manipulated data (GIS product) to the final end-customer. The aim is to improve these processes and the flow of spatial data and the related attribute data and thereby improve the overall efficiency and effectiveness of the GIS unit through the use of supply chain management. Thus this research will address one of the principal current issues in GIS as identified by the experts, such as Dangermond and Tomlinson, and will make a contribution to the further development of GIS as a science.

The following section discusses the research framework needed to answer the research question based on the topics given above that need to be addressed.

1.6 Research framework

The logical flow of chapters in this dissertation for answering the research question is illustrated in Figure 1.7 and is as follows:

> Chapters 2 to 5 give the theoretical framework of this PhD research. Geography seeks answers to the question *“why are spatial distributions structured the way they are?”* (Abler, Adams and Gould, 1971). In order to find these answers, we must bear in mind that geography incorporates knowledge from other disciplines, for example soil science is used to explain the geographical distribution of soils (Steila, 1976), economics is used in economic geography (Boyce, 1978), and political science is used as a basis for political geography (Muir, 1975). More recent examples in the context of GIS, which rely on geography, are the use of GIS in crime mapping where the GIS specialist must understand spatial theories of crime, such as environmental criminology, have a basic statistical background in order to create crime maps that are useful to law enforcement (Chainey and Ratcliffe, 2005), and be able to do geospatial analysis that relies on various statistical procedures such as standard deviation, variance, skewness, kurtosis and trend analysis (De Smith, Goodchild and Longley, 2007).
>
> This research investigates the management of GIS and proposes a new management approach, namely supply chain management. Thus in the context of this research within the discipline of Geography, it is necessary first to discuss supply chains and supply chain management in detail to form an understanding as a geographer and a GIS specialist of the nature and applicability of supply chains and supply chain management as well

as what they are used for in order to provide an answer to objective A (Chapter 2 in Figure 1.7).

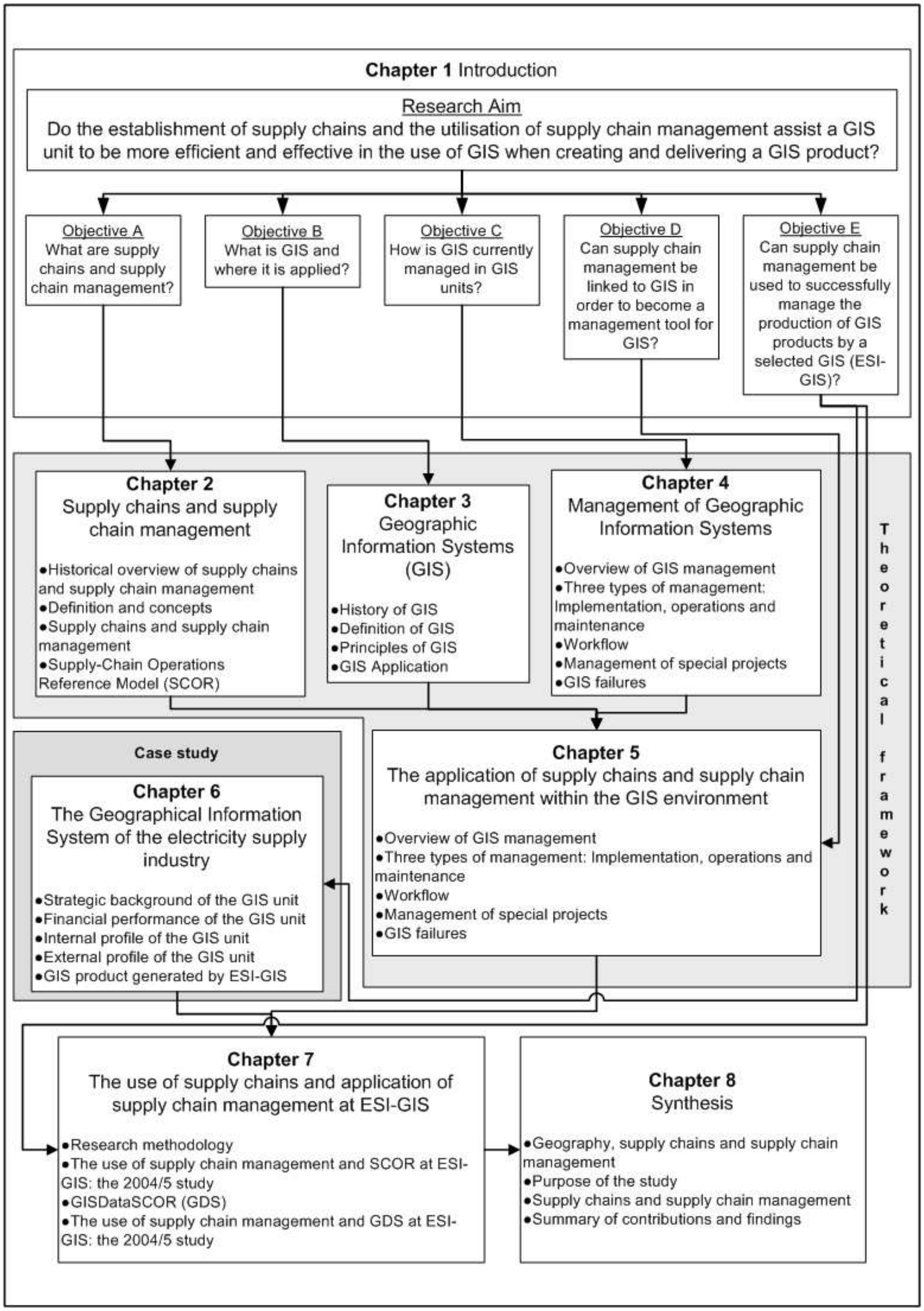

Figure 1.7: Research framework

Secondly, in order to answer objective B, GIS as such is then discussed to ascertain whether the nature of GIS lends itself to the establishment of supply chains (Chapter 3). Thirdly, current GIS management practices are discussed with the aim of determining to what extent supply chain management is being used by GIS units or organisations to give an answer to objective C (Chapter 4). Fourthly, based on the results of Chapters 3 and 4, all three of these discussions are combined to illustrate the use of supply chains and supply chain management within the scope of GIS, which will lead to an answer to objective D (Chapter 5). The bulleted paragraphs below discuss these four chapters in more detail.

- Chapter 2 discusses **supply chains** and **supply chain management** in more detail as a management tool in the manufacturing environment. Supply chain management manages the whole supply chain from the sourcing of raw materials from various suppliers, to the manufacturing process, to the warehousing of products, and to the delivery of the manufactured goods to final customer at the other end of the supply chain. The following aspects of supply chains and supply chain management will be discussed in depth: Logistics management, elaborating on order processing, inventory, transport, warehousing, and network design. Materials management looks at the procurement of raw materials and other products, warehousing of procured material, the production planning involved the different materials used as well as the quantity needed to produce the product, the handling of inbound transportation and the receiving of materials and products. Supply chain operations look at forecasting, operations planning and quality management within the supply chain. Forecasting is used to estimate customer demand for a specific product, and the supply chain is planned and managed on the basis of these forecasting results. Marketing looks at the building of supply chain relationships with both suppliers and customers with the aim of producing and marketing a specific product. Third party logistics discusses the service which is provided by organisations to facilitate a firm's logistics. Firms outsource their logistics component to third party logistics service providers, thus allowing them to concentrate on their core activities. The concept of fourth party logistics service providers is also discussed in this section. Owing to the current phenomenon of globalisation, firms have to compete in a global market in order to survive, thus necessitating the creation of global supply chains. The concept and management of global supply chains are highlighted in this section. To enable a supply chain and supply chain management to function efficiently and effectively, heavy reliance is placed on information and communication technology (ICT) infrastructure. This section examines the role that ICT plays in supply chains and supply chain management. To enable a firm to map, analyse and improve its supply chain and the management thereof, a model is used. As mentioned briefly in Section 1.3, the Supply-Chain Operations Reference (SCOR) model has been developed for this specific purpose and is the model used in this research to determine whether supply chains and supply chain management can assist a GIS unit to be more efficient and effective. The SCOR model is discussed in more detail in this chapter.

- Chapter 3 discusses **GIS as a tool and its applications**. The discussion of GIS reflects on the development of GIS over the years, the definition of a GIS and the principles of GIS. The second part of Chapter 3 examines several applications of GIS, and although it does not give an exhaustive list of applications, it demonstrates the wide variety of GIS applications that occur in practice.
- Chapter 4 discusses the **management of GIS** as described in the literature. An overview of GIS management is given, which includes the fundamentals that need to be in place as well as the principles of GIS which give firms an understanding of what a GIS is to ensure successful implementation and management of GIS. There are three types of GIS management that are applicable to

GIS. The first type is the management of implementing a GIS in an organisation, the second is the management of an operational GIS, and the third is maintenance management of the GIS. The latter involves the management of the maintenance of hardware such as printers and plotters, software that needs to be upgraded when the supplier releases a new version, and the maintenance of the spatial data and its related attribute data sets. Workflow is discussed as a management tool to automate certain aspects of the GIS product creation process in order to improve the efficiency and quality in the manufacturing of a GIS product. In this chapter, the management of special GIS projects such as the change of geographic data is also discussed. These are normally "once-off" projects that are managed using standard project management techniques. The last section in this chapter examines some reasons why the implementation of a GIS in an organisation can fail, such as the lack of understanding of the scope of the GIS, inefficient management of the GIS itself as well as the failure of the implemented GIS.

  - Chapter 5 examines the **application of supply chains and supply chain management within the GIS environment** based on the fact that definitions of GIS intrinsically describe a supply chain, as illustrated briefly in Section 1.4 as well as on the outcomes of Chapter 3 and 4. The chapter ends with a discussion on the way forward on how supply chains and supply chain management can be applied to the production of GIS products, from the sourcing of raw data, to the creation of a GIS product, to the delivery of the GIS product to the client based on the SCOR model.

- Once it has been established that supply chains and supply chain management can be utilised in the ambit of GIS, it needs to be demonstrated in practice. Chapter 6 discusses **ESI-GIS**, the GIS unit in Eskom Distribution that is used as the case study for this research. The business context of ESI-GIS in Eskom Distribution is scrutinised, which describes its mandate in Eskom Distribution. The second part of this chapter discusses ESI-GIS's GIS product portfolio. A specific GIS product portfolio is selected to determine whether supply chains and supply chain management can assist ESI-GIS to be more efficient and effective in creating and delivering GIS products in that particular portfolio.

- Chapter 7 examines the **application of supply chains and supply chain management in ESI-GIS**. The chapter is divided as follows:

    - The first section of this chapter discusses the research methodology used to determine whether supply chains and supply chain management does in fact improve the efficiency and effectiveness of a GIS in creating and delivering its GIS product to the customer. The research design is based on a combination of evaluation research as discussed by Campbell and Stanley (1966) and mixed research methods as proposed by Johnson and Onwuegbuzie (2004). Evaluation research is used to determine the impact of a policy (Campbell and Stanley, 1966). In this study the use of supply chains and supply chain management, and mixed research methods, allows both quantitative and qualitative methodologies to be used in research (Johnson and Onwuegbuzie, 2004). The reason for selecting only one case study, namely ESI-GIS as referred to above, is given in this section. This section also gives an outline of the methodology followed to conduct the field research based on the methodology proposed by Bolstorff and Rosenbaum (2003). This section ends with a brief discussion of the shortcomings, limitations and possible errors that might impact on the research.
    - The second section discusses the first analysis to determine and model ESI-GIS's supply chain and provide guidance for managing the supply chain using the method based on Bolstorff and Rosenbaum (2003) and the SCOR model version 5.0 as provided by the Supply-Chain Council (2001). This analysis was done in March 2005 for the financial year 2004/5. Several shortcomings were identified and were used to improve the second round of analysis, which also led to the adaptation of the SCOR model for the GIS environment. Despite the shortcomings, this analysis of

ESI-GIS's supply chain gave ESI-GIS enough information to implement supply chain management to improve the supply chain.

  - The third section discusses the adapted SCOR model, namely the GISDataSCOR (GDS) model in order to address the shortcomings as identified in the first analysis discussed above.
  - The second analysis was done over a period ranging from October 2006 to May 2007. As there are currently no existing benchmarks available to establish its level of performance against its peers, this second analysis was also used to establish to what extent supply chain management brought about changes in ESI-GIS. Thus this section is a sort of a test. This long period of analysis was due to the availability of staff who were involved in a major project for a customer as well as the in-depth study of ESI-GIS's supply chain using the Level 3 process elements of the GDS model. The results show that the first analysis did in fact improve the creation of GIS products and that the GIS unit could provide more data at Level 1 and 2 than in the first analysis. Chapters 6 and 7 realise objective E as illustrated in Figure 1.7.

- Chapter 8 gives a critical **evaluation** of the use of supply chain management within the GIS environment to improve the creation of GIS products, especially in monetary terms. This chapter concludes with **recommendations and directions for further research**.

1.7 Conclusion

GIS was first developed in the 1960s to satisfy the Canadian government's need for a land inventory. The subsequent further development of GIS went through several phases, starting with research and development. The current phase is known as the local and global network phase (Foresman, 1988). From the late 1970s GIS became commercially available and a wide range of users emerged, which necessitated the management of GIS. Based on this need, several works were published in the literature on the management of GIS, which included the work of Cassettari (1993), Obermeyer and Pinto (1994), Huxhold and Levinsohn (1995), Seffino *et al.*, (1999) and Li and Coleman (2004).

From the literature it can be deduced that the management of GIS can be grouped into two classes: the first is the holistic management of a GIS, which includes establishing the need for using a GIS, the placement of the GIS in an organisation, and data, hardware, software and staff issues. The second class of management is workflow, which is used to manage and automate the production of data using GIS. The production process can be automated as a whole or in parts.

When using a GIS, data need to be obtained from a source or various sources. The GIS unit manipulates and transforms the data and uses the result itself or passes the results on to another party. Using the concept of supply chains, namely supplier, producer and customer, and taking into account that materials and information move up and down between these entities, it can be assumed that supply chains are also present in a GIS unit. Based on this assumption, the operation of a GIS unit can thus be managed and improved using supply chain management, which is the aim of this research.

In order to answer the research question whether supply chains and supply chain management can be used to improve the efficiency and effectiveness of a GIS unit, supply chains, supply chain management, GIS and the current management of GIS need to be discussed in depth. Only through a thorough understanding of these concepts will it be possible to determine whether supply chains and supply chain management can improve the efficiency and effectiveness of a GIS unit.

Chapter 2: Supply Chains and Supply Chain Management

2.1 Introduction

Chapter 1 gave an introduction to the research that is the essence of this thesis, and stated the research aim in Section 1.5, namely:

> ***Can the establishment of supply chains and the utilisation of supply chain management assist a GIS unit to be more efficient and effective in the use of GIS when creating and delivering a GIS product?***

For the geographer, supply chains and supply chain management are an unknown entity and therefore careful investigation is needed as to their nature and the possibility of using them for managing GIS units. For this purpose guidance was sought from a supply chain management specialist, who also acted as co-promoter of this study. Aspects covered in this section are the definitions and concepts of supply chains and supply chain management, and the different parts of the supply chain such as sourcing, logistics, warehousing and materials management.

Supply chains and supply chain management are used either in the manufacturing industry, such as motor vehicle and electronic equipment manufacturers, or in the service industry, such as service centres that process medical aid or insurance claims. In the service industry the emphasis is on the availability of the service (Christopher, 1998). A GIS product is a physical product, either in electronic or hardcopy (such as a paper map) format, and thus the manufacturing of a product approach in supply chains and supply chain management will be used. Examples of GIS products are topographic data, land use or land cover maps, utilities such as electricity, water and gas networks and cadastral data. In the last part of this chapter the Supply-Chain Operations Reference (SCOR) model is discussed, since it is the model used to demonstrate the use of supply chains and supply chain management in the GIS arena that is used for the first analysis (see Section 1.6). The SCOR model also formed the basis for the adapted SCOR model, GISDataSCOR (GDS), which, as mentioned in Section 1.6, is used in the second analysis of the supply chain and supply chain management of the case study. An in-depth critique of supply chains and supply chain management is beyond the scope of this research. This chapter concentrates more on the nature of supply chains and supply chain management to allow a decision to be made as to whether they can be utilised as a management "tool" for GIS units. After an investigation of these aspects which are described in later chapters, they are then applied in a case study. The first part of this chapter gives an historical overview of supply chains and supply chain development.

2.2 Historical overview of supply chains and supply chain management

According to Christopher (1998), wars were won through good logistics and lost through bad logistics. The value of logistics has been common knowledge in defence forces for centuries, but it is only very recently that commercial entities have discovered the value of logistics in giving them a competitive advantage. Shaw wrote in 1915 (as referenced by Christopher, 1998) about the importance of integrated logistics, which coordinates activities amongst different role-players that are involved in supplying, manufacturing and distributing products.

Forester mentioned in 1958 (as referenced by Mentzer *et al.*, 2001) that after a period of research, progressive managers will realise that their company's well-being is dependent on relationships, the understanding of the different functions within the company and the relationship of the company with its external environment such as its market place, customers, etc. Forester then developed a computer program to simulate changes through the system.

Mentzer *et al.* (2001) mentioned that the "Beer Game" simulation and the "Bullwhip Effect", where there is an imbalance between inventory and production, developed from the work of Forester. From the late 1980s and early 1990s supply chains and supply chain management became "the topic" in the business world (Wisner *et al.*, 2005). The driver for supply chains and supply chain management was to assist the firm to provide the customer with the "right" product, at the "right" time, in the "right" condition and the "right" amount as ordered by the customer (Roberts, 2003).

Owing to the rise in popularity of supply chains and supply chain management, the Supply-Chain Council (www.supply-chain.org) was established in 1996 as a not-for-profit organisation. The members of the council consisted of people from big corporations such as Bayer, Compaq, Procter & Gamble and Lockheed Martin, to name but a few who were knowledgeable about supply chain and supply chain management. The aim of the council was to establish an industry standard supply chain implementation model. The model is known as the Supply-Chain Operations Reference Model (SCOR) (Bolstorff and Rosenbaum, 2003). See Figure 1.2 in Chapter 1 which gives a schematic overview of the SCOR model.

SCOR breaks up the supply chain into five categories, namely:

- PLAN – to assess and plan the supply chain.
- SOURCE – all the activities involved in sourcing the materials to manufacture the product.
- MAKE – all the activities involved in making the product.
- DELIVER – all the activities involved in delivering the finished product either to a warehouse, distribution centre or the customer.
- RETURN – which deals with processes involved when goods are returned to the company (Bolstorff and Rosenbaum, 2003 and Supply-Chain Council, 2005).

This section gives a brief overview of supply chains and supply chain management and where SCOR fits in. The next section reviews the definitions and concepts of supply chains and supply chain management.

2.3 Definitions and concepts

There are several definitions for describing a supply chain, which contain at least the movement of materials from the suppliers to the manufacturer and from the manufacturer to the customer as well as certain activities associated with the movement of the materials up and down the chain. The minimum number of entities in the supply chain is three, namely the supplier, the firm and the customer (Mentzer *et al*., 2001 and Mentzer, 2004). A few definitions are given below:

> *"The supply chain encompasses all activities associated with the flow and transformation of goods from the raw materials stage (extraction), through to the end user, as well as the associated information flows. Material and information flow both up and down the supply chain"* (Handfield and Nichols, 1999:2).

The definition of a supply chain given by the Supply-Chain Council (Lummus and Vokurka, 1999:11, as referenced in Hugo *et al.*, 2004:5) is:

> *"The Supply Chain – a term increasingly used by logistic professionals – encompasses every effort involved in producing and delivering a final product from the supplier's supplier to the customer's customer. Four basic processes – plan, source, make, deliver – broadly define these efforts, which include managing supply and demand, sourcing raw materials and parts, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, and delivery to the customer."*

Hugo *et al.* (2004) mention that this definition of the supply chain not only defines a supply chain but also regards the elements that are managed within the supply chain. This was the Supply-Chain Council's viewpoint of a supply chain management when it developed the SCOR model. The Supply-Chain Council added a fifth process, namely *return* (see Section 2.2), which is not reflected in their 1999 definition of the supply chain. Christopher (1998:15) gives another definition of the supply chain, namely:

“The supply chain is the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer.”

The definition of a supply chain by the Supply Chain Research Group at the University of Tennessee is expressed as follows:

“A set of three or more companies directly linked by one or more of upstream and downstream flows of products, services, finances and information from a source to a customer” (Mentzer, 2000, as referenced in Mentzer, 2004:4).

For the purpose of this research the following definition of a supply chain is used:

“The supply chains encompass all activities associated with the flow and transformation of spatial and attribute data from the raw data stage (capturing), through to the end user, as well as the associated information and money flows. Data, information and money flow up and down the supply chain.”

For the supply chain to function properly it needs to be managed. This management process is known as supply chain management. As mentioned in Section 1.3, there are a myriad of definitions defining supply chain management. Using the two definitions of supply chain management as given in Section 1.3, supply chain management for the purposes of this study can be defined as follows:

“The management of upstream and downstream relationships with suppliers and customers, including the integration of the various activities involved in the supply chain to deliver superior customer value at less cost to the supply chain as a whole.”

Thus supply chain management embraces strategic, tactical and operational management issues that will provide the company and the supply chain members with a competitive advantage over its competitors (De Kok and Graves, 2003). Upstream suppliers are *“firms or units that supply the materials/products/services to the core firm (manufacturer) that are used to produce a product for the downstream customer. They form part of the supplier network.”* Downstream customers *are “firms, units, divisions or individuals; they can be customers or end customers that buy the core firm’s products or services and form the downstream distribution network right up to the end customer”* (Handfield and Nichols, 1999).

According to Mentzer *et al.* (2001), there are three different supply chains (Figure 1.3 in Chapter 1), namely: the basic supply chain; the extended supply chain; and the ultimate supply chain. This section has briefly discussed the concept and types of supply chain and supply chain management as well as the upstream and downstream entities in a supply chain. In the next section the supply chain and supply chain management will be discussed in more detail with respect to the different role-players and functions involved in the sourcing of materials, the production of a product and the provision of the finished product to the final customer.

2.4 Supply chains and supply chain management

2.4.1 Introduction

Section 2.3 examined the definitions, concepts and types of supply chain. Firms use supply chains and supply chain management to streamline their manufacturing processes as well as to enhance their competitiveness and improve their profitability (Nix, 2001 and Roberts, 2003). Products flow from the supplier to the ultimate customer, and there is also some reverse flow of products owing to various factors such as faulty products, products that are past their sell-by date or where used products are collected either to be recycled or disposed of in a controlled manner (Roberts, 2003 and Supply-Chain Council, 2003). The reduction of inventory through the supply chain is one of the aims, if not *the* aim, of supply chain management, and the only way to do this is to keep the supply chain as visible as possible. The use and flow of information in a supply chain is one of the critical factors for maintaining visibility. A key issue is trust amongst the supply chain members, which allows for sharing of company-sensitive information (Christopher, 1998; Handfield and Nichols, 1999; Roberts, 2003 and Wisner *et al.*, 2005). Table 1.1 in Chapter 1 gives the key factors and characteristics of a supply chain.

Successful moulding of the factors in Table 1.1 into an integrated supply chain is based on the following three objectives (Roberts, 2003: *SCM 101-Unit 1: Supply Chain Management*, p 9):

- *"Recognising the final customer's service level requirements;*
- *"Deciding where to position inventories along the supply chain and how much to stock at each point; and*
- *"Developing appropriate policies and procedures for managing the supply chain as a single entity."*

Several strategies to improve the supply chain are: reduction in time usage, for example cross-docking (very short inventory holding time) or just-in-time (JIT) procedures where the inventory arrives at the plant at the time when it is needed (Roberts, 2003 and Wisner *et al.*, 2005); inventory reduction procedures using vendor-managed inventories (VMI) (Roberts, 2003); and third-party logistics (3PL) alliances, which provide a full logistics service ranging from transport, warehousing to information service provision, and results in firms concentrating their efforts at producing the products and services as required by the customer (Roberts, 2003 and Hugo *et al.*, 2004). Figure 1.5 in Chapter 1 gives a diagrammatic view of the consequences for a firm implementing successful supply chain management.

The different aspects and activities of the supply chain and supply chain management will be discussed under the following headings:

- Logistics management, which includes order processing, inventory, transportation and warehousing.
- Materials management.
- Marketing, local and global supply chains.
- Third-party logistics.
- Integrated supply chain management, which includes relationship building and maintenance, performance measures and financial issues.
- The role of information and communications technology (ICT) in supply chains.

The next section examines logistics management within a supply chain.

2.4.2 Logistics management

According to Min and Keebler (2001), logistics activities have a major impact in terms of capabilities, competitiveness and profitability of the supply chain and its members, meaning that logistics makes or breaks the supply chain. The logistics chain consists of the following activities: order processing (the procurement process, which leads to the placing of an order, will be discussed under materials management in Section 2.4.3), inventory, warehousing, network design and transport (Min and Keebler, 2001). Logistics are the key operating components of a supply chain and must be designed and managed to be consistent with the firm's and the supply chain's strategy as well as the competitive environment (Christopher, 1998; Min and Keebler, 2001; and Hugo *et al*., 2004). The following sections examine the activities in more detail.

2.4.2.1 Order processing

Demand drives the system, and it enters the supply chain through order processing. The customer enters an order (order preparation) and kick-starts the process. The other steps in order processing are:

- Order transmittal (the customer orders via mail, telephone or Internet).

- Order entry involves checking for order accuracy, availability of items ordered, the customer's ability to pay for the order and billing preparation.
- Order filling (these are the physical activities to prepare the order, which ranging from manufacture, assembling, picking, sorting to packaging for transportation)
- Order status reporting, which ensures good customer service, allows the customer to track and trace the order from start to finish, and informs when the order can be expected.
- Invoicing the customer.
- Accounting activities.
- After-sales technical and services support (Harrison, 2001; Min and Keebler, 2001 and Roberts 2003).

Once an order is placed, the product needs to be created and shipped. A product consists of various parts that are either sourced from suppliers or created in-house. These parts form part of the inventory that is kept by a company. The next section examines inventory in more detail.

2.4.2.2 Inventory

Inventory is a double-edged sword. On the one hand, it is an important component for managing uncertainty in the supply chain and enables it to function properly and help sustain the competitive advantage. On the other hand, too much inventory in the supply chain can result in disastrous effects on its members because inventory ties up much-needed capital (Christopher, 1998; Min and Keebler; 2001 and Roberts, 2003).

The aim is to plan the supply chain activities in such a way that together with good visibility along the chain, inventory is kept to a minimum level at the right location(s) in the supply chain without compromising the competitiveness and profitability of the supply chain (Min and Keebler, 2001 and Roberts, 2003). The following inventory types are typical for supply chains (Roberts, 2003):

- Cycle stock: the stock which is used in a supply chain to satisfy a demand.

- In-process stock: stock which is part of process that needs to be kept in inventory before it enters the process again at a point further down the process.
- Safety stock: the amount of stock kept in inventory to safeguard against uncertainty in the demand and in the supply chain itself.
- Seasonal stock: stock that is available to satisfy increased demand during certain parts of a year.
- Promotional stock: stock that is available when marketing runs a promotion (requires coordination between production and marketing).
- Dead stock: stock in inventory that is no longer of use to the supply chain before it is disposed of in an appropriate manner.

The following are costs associated with inventory:

- Capital cost is the percentage of the value of the product (capital) that is tied up in inventory, i.e. if the capital cost of keeping inventory is 20%, then if the value of the product is R100.00 the capital cost is R20.00 per annum.
- Storage costs, including the purchase or rental of the warehouse itself, lighting and handling costs (forklifts, administration, drivers, etc.)
- Inventory service costs are insurances and taxes associated with inventory.
- Inventory risk costs are costs associated with shrinkage, obsolescence, damages, etc. (Min and Keebler, 2001 and Roberts, 2003).

Christopher (1998) mentions four different approaches to inventory management. Each of these approaches is discussed briefly:

Economic Order Quantity (EOQ) is used to order the correct amount of inventory and is based on a formula that balances the costs involved to keep inventory (space, handling, etc.) against the cost of replenishing the inventory (cost of issuing the order, delays, etc.) and/or the cost of setting up the production of a commodity. One major shortcoming of this method is that one is forced to carry more inventory (to safeguard against uncertainties) than is actually required over the complete order cycle, which leads to higher costs than necessary and is ultimately recovered form the client. According to Min and Keebler (2001:245), EOQ is appropriate *"in a pull (reactive) system involving independent demand items (unrelated to other demand items) for a single-facility solution."*

Another approach to manage inventory apart from EOQ is the ABC inventory control system, where the inventory is categorised into type A, B and C inventory. Type A inventory is the high-priority inventory, which is about 20% of the inventory but makes up 80% of annual money usage. Type B is about 40% of the inventory which uses about 15% of the money. Type C are those inventory items that use 5% of the money. Type A inventory is placed in such a position in a warehouse that it can be accessed easily, since this is high-turnover inventory. Type C inventory is placed in a warehouse where access to the inventory is not critical (Roberts, 2003 and Wisner *et al.*, 2005).

Materials Requirement Planning (MRP) is used to plan the required materials and components that need to be supplied to fulfil the demand for production, which in turn is determined by the demand for the end product (Roberts, 2003). One of MRP's main objectives is to keep inventory to a minimum level as required for production. To achieve this objective a MRP system takes into account existing and planned materials and components in inventory as well as when they are required for production. The other goals are to ensure the availability of the materials and components when needed and to "plan manufacturing activities, delivery schedules and purchasing activities" (Roberts, 2001: SCM 103 Unit 1 p 33). MRP systems are optimally applied "in a push (proactive) system of dependent demand items where a system-wide solution is desired (Min and Keebler, 2001:245)". MRP developed in recent years into Materials Resource Planning (MRP-II), which includes the ability to do "what-if" analyses, production scheduling, inventory control as well as financial and accounting functions (Wisner *et al.*, 2005:169). The latter authors also mention that MRP-II evolved into the Enterprise Resource Planning (ERP) system which encompasses all the activities in an organisation from production to customer and supplier relationship management. An example of an ERP system is SAP (Wisner *et al.,* 2005).

Distribution Resource Planning (DRP) is mostly used with MRP and focuses on the out-bound logistics activities of a manufacturing entity to keep inventory at an appropriate minimum level. DRP helps the company to improve its service to its customers by decreasing possible stockout of required products. Companies use DRP systems to improve their distribution centre operations. To be able to do this, DRP systems need to link with MRP systems to establish when the product will be available for distribution (Roberts, 2003). DRP systems are preferred "*in a push (proactive) system of independent demand items where a system-wide solution is desired* (Min and Keebler, 2001:245)". DRP systems are also integrated into MRP-II and ERP systems (Wisner *et al.*, 2005).

Just-In-Time (JIT) is, according to Christopher (1998), a philosophy (based on the kanban system of the Japanese (Roberts, 2003)), as well as a technique. It is based on the principle of implementing an activity only when it is necessary wherever possible. It is a "pull" system which is driven by demand at the end of the supply chain pipeline (the market), and the materials and components are pulled into system whenever needed by the same demand. In the JIT system it is required that inventory be shipped in small quantities more often to meet the precise time requirements of the customer, wherever he is in the pipeline (Christopher, 1998, Roberts, 2003, and Wisner *et al.*, 2005). According to Roberts (2003) and Wisner *et al.* (2005) four elements form the basis of JIT:

- Zero or very small volume inventories.
- Short lead times.
- Frequent replenishment quantities
- High quality or zero defects.

This section has given an overview of inventory and several methods of how to manage inventory as well as some cost-saving measures. Since inventory consists of goods that are moved around the supply chain, these goods need to be transported from one location to another. The transportation of goods is discussed in the next section.

2.4.2.3 Transportation

"*Transportation is the spatial linkage for the physical flows of a supply chain.*" (Min and Keebler, 2001:246.) Transportation is the movement of goods in time and space and the aim is to get the right product, in the right quantity, at the right time, to the right customer at the least possible cost. Transport also acts as temporary storage of materials, components or finished products in transit before delivery at the right place in the supply chain, which in turn saves in inventory costs. Speed and reliability of the delivery of goods is the main issue in transportation, which in turn improves the profitability of the supply chain (Min and Keebler, 2001 and Wisner *et al.*, 2005).

According to Wisner *et al.* (2005) there are four legal forms of transportation. Common carriers offer their services to everybody and are subject to strict rules and regulations. South African Airways (SAA) is an example of a common carrier. The second type of a carrier is a contract carrier which services a specific client based on specific contractual agreements. These carriers are also subject to rules and regulations. Exempt carriers are the third type and are exempt from certain rules and regulations based on the exempt goods they carry. Examples of exempt goods are coal and newspapers. The last carrier type is the private carrier, i.e. the firm has its own carrier to deliver goods. An example is British American Tobacco in South Africa which have their own fleet of delivery vehicles. There are several modes of transportation that can be used to distribute goods between supply chain members. These modes are air carriers (SAA or Comair), motor carriers (from motor cycles to big trucks), rail carriers (Spoornet), water carriers (such as Safmarine) and pipelines (e.g. the fuel pipeline between Durban and Gauteng operated by Petronet).

Intermodal transport is when goods are shipped first in one mode of transport and then in a different mode to take it to its end destination. The most common example of intermodal transportation is the movement of containers. They are transported by truck from an inland port (e.g. City Deep in Johannesburg) to a seaport (Durban), loaded onto a ship and transported to another port and loaded at the port again onto a truck to be delivered to their final destination (Wisner *et* *al.*, 2005). To facilitate and improve the movement of goods, companies make use of third-party logistics services, which are discussed in more detail in Section 2.4.6. Goods have to be loaded for transportation at their points of origin and off-loaded at their destinations. Goods for on and off-loading are stored in warehouses. Warehousing of goods is discussed in the next section.

2.4.2.4 Warehousing

A warehouse is a location where raw materials, work-in-progress materials and finished goods are stored by the supplier, manufacturer, wholesaler or retailer. The abovementioned goods are held for a specific time period and add costs to the end product due to storage costs, handling costs, etc. Therefore the main aim is to design the warehouse and the time a product needs to be warehoused to such a level that it carries the minimum cost (Min and Keebler, 2001; and Hugo *et al.*, 2005). Warehouses are mainly used to store goods or function as a cross-docking facility where goods, which arrive as truck loads (TL), are broken down into smaller quantities, commonly referred to as less-than-truck loads (LTL) and then shipped out to customers, or where LTLs are received and consolidated into TLs, or the goods can be consolidated for customers (Hugo *et al.*, 2005). There are three types of warehouses, namely private, public and contract. Private warehouses belong to a specific company and public warehouses provide warehousing functions to various companies. Users who enter into long-term contracts with warehouse operators use contract warehouses. The contract includes other activities such as logistical services and transport (Wisner *et al.*, 2005 and Hugo *et al.*, 2005). Warehousing functions, besides cross-docking, include:

- Stockpiling (i.e. stockpiling of goods that are very seasonal to meet demand).
- Stock mixing (i.e. sorting out larger shipments into smaller shipments).
- Postponement (where goods that are manufactured are stored in a warehouse but the goods are not labelled. The labelling will be done in the warehouse just before the shipment is made).

- Reverse logistics (the warehouse acts as a collection point from where returned goods are then disposed of).
- Spot stocking (goods are stocked in greater quantities than usual to cater for a surge in demand during peak times, such as Christmas, or key agricultural activities such as the planting season).
- Contingency protection (goods are stored a location other than a plant or key market to keep the supply chain going owing to an impending strike or a natural disaster such as a hurricane) (Min and Keebler, 2001; Hugo *et al.*, 2005 and Wisner *et al.*, 2005).

Storing goods in a warehouse costs money and the costs can be divided into three main categories: the rental or purchase of the physical warehouse. the energy that is used for lighting, air-conditioning, etc., and the handling of the goods by people and/or machinery (Min and Keebler, 2001).

According to Min and Keebler (2001), Hugo *et al.* (2005), and Wisner *et al.* (2005), the following activities are typical of a warehouse:

- Receiving of goods (verification and matching to purchase order).
- Putting away of goods at assigned locations in the warehouse.
- Storage of goods after they have been put away.
- Order picking of goods (goods are moved from the bulk storage area into bins from which orders are assembled).
- Packaging and labelling of goods after they have been assembled.
- Staging of packaged and labelled goods on a loading dock to facilitate shipping, which includes loading of the vehicle and preparation of shipping documents.
- Housekeeping of the warehouse, which includes planning of the layout to place goods in such a way that they are easily accessible when needed.

Several warehousing designs have been developed through research to optimise the flow of goods being handled in a warehouse, which in turn adds to cost savings (Roberts, 2003 and Hugo *et al.*, 2005).

2.4.2.5 Network design

A supply chain network, according to Handfield and Nichols (1999), Min and Keebler (2001), and Hugo *et al.* (2005), consists of suppliers, manufacturers/assembly, warehouses, distribution centres and retail outlets. Between these elements there is a flow of raw materials, work-in-progress inventory and finished products as well as a flow of finances and information between the elements.

The aim is to design the supply chain network in such a manner as to save costs in production, inventory and transportation as well as to satisfy customer demand as efficiently and quickly as possible, without losing the quality of the finished product (Min and Keebler, 2001).

If the members of a supply chain decide to optimise their network, Hicks (1997 as referenced in Min and Keebler, 2001), suggests the following steps to solve a supply chain network problem:

Step 1: Identify the problem.

Step 2: Model the problem with respect to costs, current locations of warehouses, suppliers, distribution centres, retailers, amount of raw materials and goods moved, etc.

Step 3: Apply a technique, whether mathematical, computational or heuristic, to find a good solution to the model as developed in Step 2.

Step 4: Use the solution in Step 3 to improve the real-world situation.

Another solution is to outsource the biggest part of the network to third-party logistics (3PL) service providers, who take over the warehouse, distribution centre and transportation functions. Examples of 3PL service providers are UPS and FedEx (Roberts, 2003).

Competition today, according to Min and Keebler (2001) and Roberts (2003), is based on the principle of whose supply chain performs the best and the cheapest, and the uniqueness of the products and services offered to the end customer. To be able to achieve this and to sustain it, a supply chain must have superior logistics. Good logistics are necessary to enable the movement and storage of materials at the different stages in a supply chain, but if the materials are not managed properly all the effort of having excellent logistics management will be not optimal. The next section looks at materials management within a supply chain.

2.4.3 Materials management

The coordination of the inbound system of a firm's logistics, which includes order placing, is materials management. It is important to align a firm's inbound system with its outbound system (i.e. the delivery of products to the customer) to allow for an effective and efficient supply chain. Coordination between the two systems can only be achieved through the flow of information between the two systems and up and down the whole supply chain (Roberts, 2003).

According to Roberts (2003), materials management in a supply chain consists of the following activities, which is discussed in more detail below:

2.4.3.1 *Procurement*

Procurement comprises all the activities needed to acquire the products and services in line with the firm's requirements to deliver the product as per customer demand. Rapid changes in products are caused by ever-changing consumer demand place pressure on how firms procure their raw materials or goods from their suppliers. This in turn forces suppliers to become more flexible and reliable in their delivery of requested goods to their customers, as well as be willing to be a part of a supply chain and share its risks and benefits. Firms, to be more competitive, are outsourcing their non-core business activities to third-party service providers. This in turn forces the firms to manage the supply of goods and services to ensure the delivery of their products and services to their customers at the other end of the supply chain (Nix, 2001; Roberts, 2003 and Hugo *et al.*, 2005). Roberts (2003: SCM 104 Unit 1 p 29) indicates the following basic activities in the procurement process:

- Identify a need to procure an item or items (raw materials, products or service). This is based on requirements inside the firm or influenced by customer demand.
- Define and evaluate user requirements of the item that need to be met.
- Once the requirements are met, decide whether it is cheaper to make the item itself or to procure it.
- Identify the type of purchase, i.e. straight re-buy or modified re-buy from existing suppliers (the latter means changing from one existing to another existing supplier) or a new buy. A new buy means identifying a new supplier from which to buy.
- Conduct a market analysis of possible suppliers of the item and base the buying strategy on key indicators within that market.
- From the market analysis, identify possible suppliers.
- Pre-screen the identified suppliers based on demand criteria.
- Evaluate the remaining supplier base based on the best fit of negotiable user requirements using several methods such as competitive bidding or benchmarking.
- Receive delivery of the procured item from the selected supplier.
- Make a post-purchase performance evaluation to establish that the item meets the preset requirements; if not, then corrective action must be taken.

The above activities can be managed in a four-step process (Roberts, 2003), namely:

- Determine the type of purchase (point 4 above).
- Determine the necessary level of investment with respect to time and information, i.e. the type of item determines how much time will be spent on procuring the item and how much information will be gathered. For generic items or commodities (Harrison, 2001) that have a low risk and value, little time and information is needed for procurement, whereas critical items or capital equipment (Harrison, 2001) have a high value and

risk, a lot of time and information has to be spent on procuring the item. Other items are commodities or jobbing and fashion items (Harrison, 2001) which have a low risk and a high value, and distinctives or durables (Harrison, 2001) which have a high risk and a low value.

- Perform the procurement process (selection, evaluation, receiving and performance testing).
- Evaluate the effectiveness of the procurement process.

With the advent of the World Wide Web, Internet and e-commerce, more and more companies have turned to purchasing via the Internet using a facility called e-Procurement (Roberts, 2003 and Hugo *et al.*, 2005). e-Procurement has the following benefits according to Roberts (2003) and Hugo *et al.* (2005):

- Lowering of operating costs through the reduction in paperwork, faster sourcing time of ordered items, and improved control over inventory and spending.
- Improvement in procurement efficiency by finding new supply sources more quickly, better communication with suppliers, better use of personnel and lower cycle times between ordering and receiving.
- Reduction in procurement prices based on better comparisons of prices between competitors.
- Suppliers can react faster to customer needs. All the aspects above reduce the overall price paid.

According to Roberts (2003), the main disadvantages of using e-Procurement are issues concerned with e-commerce security, the lack of face-to-face interaction between buyer and seller (it becomes impersonal), and the lack of standards and protocols with respect to technology and system reliability..

2.4.3.2 Warehousing

Warehousing deals with the handling and storage of ordered items and has been discussed in more depth in Section 2.4.2.4.

2.4.3.3 Production planning

Production planning is based on the estimated demand for a specific product. It determines the quantity of the product to be produced, the time needed for production, and the availability of machinery and manpower to produce the product in the quantity required within the specified time frame. Production systems are determined by type of product demand and have to be taken into account during production planning. These are according to Zacharia (2000b, as referenced in Mentzer, 2004:11) as follows:

System 1: A production system that reduces the cost and increases the efficiency of functional products in a stable market.

System 2: A flexible production system that can react with speed is used for highly innovative products in an uncertain and constantly changing market.

System 3: A dispersed production system where product components are manufactured at a specific location and assembled at another location as a cost-efficient production system in a globally competitive market.

System 4: Products that are sold in markets where the customer demand changes rapidly and the products become obsolete quickly are best manufactured in a production system where the products are built-to-order and postponement is used. Postponement is used where final finishing of the product is done close to the market. An example is the textile industry, where the label is affixed to a garment just before it is shipped to the customer.

2.4.3.4 Inbound transportation

Inbound transportation is the spatio-temporal link between the buyer and the seller (see also the discussion on transportation in Section 2.4.2.3).

2.4.3.5 Receiving

This is the physical reception of ordered goods at the warehouse, the verification of the received goods against the purchase order, quality control of the goods (see below), payment for received goods and the return of defective goods.

Quality Control – Checks the compliance of ordered products against design specifications, the ease of use and maintenance of the product, compliance with industry standards such as ISO 9000 and ISO 14000 standards suites.. Owing to the quantities ordered, quality control is done on a sample basis. Samples are tested against the criteria determined between buyer and supplier. If the sample does not meet the criteria, the whole shipment is rejected and returned to the seller.

Reverse logistics – Reverse logistics deals with the receiving and disposing of returned goods or materials, salvage, scrap, excess and obsolete materials or goods. Some of the goods or materials are recycled either for re-use or into new products that are sold to customers. The rest needs to be disposed of in an appropriate manner. Owing to pressure on firms to be more environmentally aware (including ISO 14000), firms are requesting their customers to return excess and obsolete products to the supplier for appropriate disposal. There are also companies that provide reverse logistics services to manufacturers (Roberts, 2003 and Wisner *et al.*, 2005).

The cost effective and correct handling and management of materials is important to ensure an effective and efficient supply chain. This section has discussed the activities around materials handling and management such as inbound logistics, inventory and quality control. This and the previous section have examined materials management and logistics and how they are important to the supply chain and supply chain management. The correct materials and finished goods have to be moved along the supply chain, and the next section looks at operational issues with regard to the supply chain and supply chain management to establish which materials and finished goods need to be moved along the supply chain.

2.4.4 Operations

2.4.4.1 Introduction

In this section operational issues regarding the supply chain are discussed. According to Roberts (2003), and Wisner *et al.* (2005), customers dictate the supply chain. Customers demand better quality products and if they do not get them from one supplier, they switch to another supplier. Customers create a "pull" environment where their need dictates the product that must be manufactured. To be able to fulfil the customers' need and exceed his expectations there are certain operational activities that are necessary for this. These activities are grouped broadly into forecasting, operations planning and quality management. Each group is discussed in more detail in this section.

2.4.4.2 Forecasting

Forecasting is divided into two groups, namely demand forecasting and techniques used in demand forecasting, and collaborative planning, forecasting and replenishment (CPFR). Forecasting is used to establish future demand by customers using different sources of information provided by the different partners in the supply chain. Since the results of a forecast are used to plan the supply chain and production activities, accurate forecasts are necessary. A good forecast results in lower inventory levels, reduction in stock-outs, smoother production plans, lower costs of producing a product and improved customer service. Another benefit of a good forecast is that it will lead to a better match between supply and demand. The downside is that poor forecasts result in the bullwhip effect, which leads to stock-outs, lost sales and poor customer service (Wisner *et al.*, 2005).

Two types of forecasting techniques are used to forecast demand. The first is quantitative forecasting techniques, which use mathematical models and historical data. Several time series models are used to forecast demand, such as the Simple Moving Average Forecasting model or the Associative Forecasting model, which use regression analysis. For in-depth discussions of these models, the reader is referred to Wisner *et al.* (2005). The second type of forecasting technique is the qualitative technique, which relies on the opinions and intuition of experts. Examples of qualitative techniques are the Jury of Executive Opinion where a panel of experts give various opinions based on experience, and the demand is established by general consensus. This technique is used in the textile industry. Another method is the Delphi method where a panel of experts give and rank their opinions. There are several iterations of the process until consensus is reached. The advantage is that it levels the playing fields, where the dominant person is equal to the others, since the experts are not together in one room. The disadvantage is that it is time consuming and can be expensive to run. Two other techniques are the Sales Force Composite, where the sales force give input based on their sales to the customer, and consumer surveys in which the consumer fills in a questionnaire based on the products they use (Wisner *et al.*, 2005). There are several methods to determine forecast accuracy, such as the mean absolute deviation (MAD) or the mean squared error (MSE). These methods all use the forecast error as input. The forecast error is the difference between the actual quantity of goods sold and the value predicted by the forecast (Wisner *et al.*, 2005). According to Wisner *et al.* (2005) there is a range of sophisticated forecasting software such as Forecast Pro, Forecast Unlimited, SmartForecastsTM and MS Excel and Lotus 1-2-3.

To improve forecasting and to react to the forecast, supply chain members do collaborative forecasting, which includes promotions, change in demand, store openings and closure, and impact of competitors. This collaborative effort is known as Collaborative Planning, Forecasting and Replenishment (CPFR) (Hugo *et al.*, 2004, and Wisner *et al.*, 2005). The definition of CPFR according to the American Production and Inventory Control (APICS) is as follows (given in Wisner *et al.*, 2005:143):

> *"A collaboration process whereby supply chain trading partners can jointly plan key supply chain activities from production and delivery of raw materials to production and delivery of final products to end customers. Collaboration encompasses business planning, sales forecasting, and all operations required to replenish raw materials and finished goods."*

The objective of CPFR is to optimise the supply chain, to improve forecasts, to deliver the right product in the right quantity at the right time and right place, to reduce inventory, to avoid stock-outs and finally to improve customer service. To enable CPFR to function properly, supply chain members must share their forecasting information.

Wisner *et al.* (2005:143) list the following CPFR benefits to supply chain members:

- *"Strengthening partner relationships.*
- *Providing analysis of sales and order forecasts upstream and downstream.*
- *Using point-of-sale (POS) data, seasonal activity, promotions, new product introductions, and store openings and closures to improve forecast accuracy.*
- *Managing the demand chain by exception proactively eliminates problems before they appear.*
- *Allowing collaboration on future requirements and plans.*
- *Using joint planning and management of promotions.*
- *Integrating planning, forecasting and logistics activities.*
- *Providing efficient category management and understanding of consumer purchasing habits.*
- *Providing analysis of key performance metrics such as forecast accuracy, product lead times and inventory turnover to reduce supply chain inefficiencies, improve customer service, and increase sales and profitability."*

Since CPFR includes all members of the supply chain to ensure a cost-efficient and high-quality response to customer needs and expectations, it has to be implemented across the supply chain members. Hugo *et al.* (2004) and Wisner *et al.* (2005) list the eight implementation steps to implement a CPFR amongst supply chain members:

- Develop collaboration arrangement.
- Create joint business plan.
- Create sales forecast.
- Identify exceptions for sales forecast.
- Resolve/collaborate on exception items.
- Create order forecast.
- Identify exceptions to order forecast.
- Order generation.

CPFR enables the members of the supply chain to create a mutually agreed upon plan to respond to customer demand. The members also take responsibility for their actions, and the benefits to each member are greater than if the member had operated on his own. According to Wisner *et al.* (2005) the biggest implementation challenges facing CPFR is the difficulty for companies belonging to a supply chain to change internally to be able to fit into the supply chain/CPFR framework. The cost of implementation could be a challenge, especially if the benefits and the return on investment are not clear. The third challenge is to change the operating environment to enable the exchange of data, the alignment of business plans and processes, to name but a few. Finally, the biggest challenge for the members is to create an ambience of trust amongst them, since CPFR is dependent on information sharing amongst the members. The best-known CPFR software is Manugistics, i2 Demand Collaboration and SyncraXt (Wisner *et al.*, 2005).

Once collaboration between members and the forecasts has been established based on CPFR, the supply chain members need to plan the productions. The following section discusses the various aspects of planning production from long-term to short-term perspectives.

2.4.4.3 Operations planning

Wisner *et al.* (2005) indicate that operations scheduling and inventory management are the most critical activities in the sourcing of raw materials, the production and distribution of the final product based on the forecasts made as discussed in the previous section. They balance capacity (labour, equipment and materials) with output. Operations planning within the supply chain occur on three levels which are hierarchical in nature. The first level is the long-term planning, the second level is the medium-term planning and the third level is the short-term planning horizon. Each higher level precedes the lower level, i.e. the long-term plan determines the medium-term planning and in turn influences the short-term plans. Each level consists of a production and capacity plan that will influence the shorter-term production and capacity plan. Each level is discussed briefly in the following paragraphs.

a) Long term: Aggregate Production Plan and Resource Requirement Planning

The long-term planning horizon is one year, with a roll-over every three to four months. The Aggregate Production Plan (APP) disaggregates the demand forecast into time periods, normally in months, and determines the number of hours and the workforce needed to meet the demand for a specific product for each time period. The unit used in APP is labour hours needed to complete the tasks. The results feed into the Master Production Schedule, which is the medium-term plan (Wisner *et al.*, 2005).

Three different production strategies can be used to determine the APP. The first strategy is known as the Chase Production Strategy, which adjusts capacity to match the demand pattern. The workforce size is variable, whereas the finished goods inventory is constant. Hiring and dismissing workers as the capacity varies means a variable workforce. This strategy works well in make-to-order firms. The second strategy is the Level Strategy, where the output rate and the workforce are constant but the inventory levels and the backlogs vary. Backlogs are addressed in "quiet" periods. This approach is used in make-to-stock firms using highly skilled labour. The third strategy is the Mixed Strategy, which is a combination of the first two strategies. The firm employs a stable core workforce and meets the increase in demand by using overtime, sub-contracting and a part-time workforce. The resources needed for APP are planned using the Resource Requirement Planning (RRP) method. RRP looks at the gross labour and machine hours needed to meet the production demand (Wisner *et al.*, 2005).

The results of the APP feed into the MPS, and the RRP feeds into the Rough-cut Capacity Plan. These are the medium-term planning strategies to meet the production demand.

b) Medium term: Master Production Schedule and Rough-cut Capacity Plan

The Master Production Schedule (MPS) disaggregates the Aggregated Production Plan (APP) by listing the exact end products that need to be produced at the end of a specific time period. The MPS takes into account orders received and other expected sales and balances them with the production capacity. The final production schedules indicate what needs to be purchased by providing sufficient lead times to procure specific items for specific target dates and assist the supply management to keep orders and deliveries in line with the production schedule (Hugo *et al.*, 2004 and Wisner *et al.*, 2005). For the service industry the MPS ensures that the available professionals are not overbooked with respect to service delivery. The booking time slots for service delivery are continuous until the schedule is filled to capacity. The appointment book of a medical doctor or lawyer is an example of an MPS for the service industry (Wisner *et al.*, 2005).

MPS provides the required production quantity to meet the demand based on all the sources involved in the production. The MPS then uses this information to compute the requirements for all the time-phased end items. To counter any nervousness in the production system, MPS makes use of a time fence system where the planning horizon is broken into parts, namely: a firm segment, which is the demand time fence to produce the end product as required based on the forecast and confirmed orders and is fixed; and a tentative segment, which is the planning time fence starting when the firm segment ends. The latter makes provision for unexpected changes in demand. The firm segment can only be changed by senior management, whereas the planning segment can be changed by the master scheduler to meet demand. The MPS also indicates whether extra orders can be handled in a specific time period or not. If the MPS can handle extra orders, meaning more is produced than committed to customers, the uncommitted portion is known as available-to-promise, which allows for quick response to a sudden change in customer demand (Wisner *et al.*, 2005).

The Rough-cut Capacity Plan (RCCP) looks at the availability of staff during a specific time period as specified by the MPS to ensure that the capacity is not stretched. MSP and RCCP feed into Material Requirement Planning (MRP) and Capacity Requirement Planning respectively. MRP is used to plan the production at its nuts-and-bolts level to meet the required demand.

c) Short term: Material Requirement Planning and Capacity Requirement Planning

This section elaborates on Material Requirement Planning (MRP) as discussed in Section 3.4.2.2. Before MRP and Capacity Requirement Planning are discussed, two concepts need to be elucidated since they have a direct influence on MRP. These concepts are:

- Dependent demand and independent demand: Dependent demand is the inventory that is used during the manufacturing of the final product. These are the exact materials required as expressed in the Bill of Materials (BOM). Independent demand is the inventory that consists of the final product and is subject to customer variability. The independent demand forecast is based on market conditions and customer demand.
- Bill of Materials (BOM): BOM is an engineering document detailing an inclusive list of all the parts and assemblies needed to manufacture the final product. The BOM uses levels to indicate parent-component relationships. Level 0 is the final product and Level 1 is where final assemblies and parts are manufactured before they are assembled to create the final product. Level 2 consists of parts and assemblies needed to create the assemblies and parts for Level 1, etc. A super bill of materials is a simplified BOM, which is used for planning purposes as well as to indicate different models of the same product (e.g. Fiat Palio 3-door and 5-door with engine capacities of 1.2 and 1.4 litres (petrol) and 1.7 (turbo diesel), i.e. six different models). The super BOM uses forecasts of demand for model breakdowns. BOM provides input for MRP (Wisner *et al.*, 2005).

Material Requirement Planning (MRP) is, according to Hugo *et al.* (2004) and Wisner *et al.* (2005), a computer-based system that uses inputs from the Master Production Schedule (MPS) and Bill of Materials (BOM) to synchronise the supply of parts, components and assemblies to the production process with the aim of keeping the inventory to its minimum, without disrupting the production process. Hugo *et al.* (2004:149) define an MRP as follows:

> *"An MRP system is a computerised information system that integrates the scheduling and control of materials through logically related records, procedures and decision rules with the master production schedule (MPS) into time-phased net requirements for each inventory item."*

Independent demand information from the MPS, the parent-component relationships from BOM, as well as the related planning factor and lead-time information, and the inventory status of parts, components, assemblies and final product are then compared with the net requirements coupled with appropriate lead times to ensure that the orders for materials are placed and received, and the materials released at the correct time to ensure disruption-free manufacture of high-level components as described in the BOM (Hugo *et al.*, 2004 and Wisner *et al.*, 2005).

Hugo *et al.* (2004:154) list the following as the main characteristics of a MRP system:

- It is an electronic system that enables the MRP to calculate the necessary amount and type of materials needed in inventory for timely release into system for a wide range of products for a specific time period.
- It keeps inventory to a minimum by the synchronisation of the flow of materials with production scheduling.
- The MPS is the departure point for all the MRP calculations, inventory and material flow control.

- It provides a more reliable source of information with regard to the demand of materials and components than any other inventory or forecasting systems
- It can be utilised by a wide variety of manufacturers owing to the system's ease of customisation to suit the needs of a specific manufacturer.

The MRP was developed over time into a Material Resources Planning (MRP-II) system and then as an Enterprise Resource Planning system. The latter two systems are briefly discussed in Section 2.4.2.2. The Capacity Requirement Planning (CRP) uses information from the MRP to determine the capacity required to manufacture each component and assembly as specified in the MRP (Wisner *et al.*, 2005). Inventory plays an important role in an MRP. (For a more detailed discussion on inventory and inventory management see Section 2.4.2.2.). The present section has looked at operations planning over several time periods as well as the capacity required to carry out the operations. The next section examines specific processes such as Just-in-Time (JIT) and Efficient Consumer Response (ECR) to enable the operations plan to be carried out.

a) Process planning: Just-in-Time, Quick Response and Efficient Consumer Response

The aim of supply chain management is to keep the cost as low as possible, and obtain high levels of quality and responsiveness throughout the supply chain. Quick Response (QR), Efficient Consumer Response (ECR) and Just-in-Time (JIT) are such techniques for making supply chain management successful. QR, according to Christopher (1998), Hugo *et al.* (2004) and Wisner *et al.* (2005), was developed by the textile industry to enable it to meet changes in customer demand with changing fashion trends. The aim of QR is to provide products to customers as quickly as possible on a continuous basis so that inventory levels are kept to a minimum throughout the whole supply chain (Hugo *et al.*, 2004). QR is dependent on point-of-sale (POS) data and electronic data interchange (EDI) (for exchange of business documents, i.e. electronic orders, invoicing, etc.) to function properly. POS data is sensitive information to a retailer and there has to be trust between the retailer and the manufacturer for the retailer to share his POS data (Christopher, 1998 and Hugo *et al.*, 2004).

ECR is the system used in the retail industry to ensure that the right goods arrive at the right place and time at the least cost (Christopher, 1998; Hugo *et al.*, 2004 and Wisner *et al.*, 2005). EDI and supply chain relationships between suppliers and retailers are the main drivers of ECR. The main goal of ECR is to eliminate, or keep to the minimum, those supply chain costs that do not add to customer value. This is achieved by activities such as the reduction of duplication, the reduction of inventory, as well as cycle time within the supply chain (Christopher, 1998 and Hugo *et al.*, 2004). ECR aims to provide efficiency in four key areas of the retail industry business, namely (Christopher, 1998 and Hugo *et al.*, 2004):

- New and efficient product introduction: ECR improves the success rate of the introduction; the reduction in time to get the new product to the market; the return on investment owing to larger quantities being sold; and quality improvement and reduction in supply chain costs.
- Efficient trade and consumer promotions: ECR can be used to offer improved incentives such as rewarding sales by retailers and the number of goods bought by retailers; improved customer targeting; and co-operation across the supply chain using a process called forward commitment where retailers can make use of pricing discounts without having to keep large inventories themselves.
- Efficient range and store assortment: ECR is used to enable retailers to match their consumers' needs with regard to products and services and simultaneously to increase the profitability of the supply chain by utilising space efficiently in a store. Category management is used to assist in matching customers' needs, where each category is managed as a business. Optimal product mix per category per store is achieved by analysing point-of-sale (POS) and EDI data and bar coding of products.
- Efficient product replenishment: ECR is used to improve on-the-shelf availability by reducing/eliminating stock-outs, and to reduce supply chain costs and inventory.

The last key supply chain process to be discussed is Just-in-Time (JIT). JIT was discussed briefly in Section 2.4.2.2 under inventory management. In this section JIT is discussed in more detail.

JIT is, according to Christopher (1998), Hugo *et al.* (2004) and Wisner *et al.* (2005), a philosophy or mindset which embraces continuous problem solving within the supply chain to eliminate waste and to have respect for people. Waste can be excess inventory, time wasted by workers assembling a component, or inefficient information technology systems. JIT works on the “pull” through the supply chain, which means that assemblies and components will only move when required by the next process in the supply chain. The aim of JIT is to reduce lot sizes (inventory), processing times, safety stocks, wasted worker and material movements, and variability in the manufacturing process and defects. The net result of JIT is reduced costs and response times and improved quality.

To achieve this aim, JIT synchronises the movement of goods from the supplier to the manufacturer, the movements of goods internally by the manufacturer and the movement of the finished goods to the customer. With this synchronisation of the movements of goods and finished goods, inventories of raw materials, work-in-progress and finished goods are kept to a minimum or eliminated (Christopher, 1998 and Hugo *et al.*, 2004).

JIT consists of eight main elements, all or some of which will be used by manufacturers depending on the products that they produce. These elements are (Wisner *et al*., 2005):

- **Waste reduction**, which includes the reduction of unused inventory, unnecessary material movements and rejects.
- **JIT partnerships** – customers work with the firm to eliminate waste and to improve the speed of delivery and reduction in costs through close customer relationships. The suppliers are seen as partners.

- **JIT layouts –** inventories such as work-in-progress inventories are placed close to where the action is and assembly area layouts are designed to minimise the movement of goods and workers, which allows for the smooth flow of goods through the supply chain.
- **JIT inventories** are kept to the minimum, which allows for the identification of processing problems that are managed and solved.
- **JIT scheduling –** to maintain low or no inventories, the firm produces small batches of variable products, which require more frequent supplies from suppliers and deliveries to customers.
- **Continuous improvement** is achieved owing to the shortened supply chain. This allows problems in the process to be identified much more quickly, which can be managed and corrected speedily, as well as better quality control of goods received from suppliers.
- **Workforce commitment** is entrenched by cross-training of the workers as well as empowering them to identify and fix problems, and to carry out quality control.
- **JIT II** is where the supplier places an employee in the buying firm (customer) who acts as a buyer for the customer. This reduces lead times since the supplier has access to the information systems and can place orders more quickly.

This section has discussed the different operations and processes within a supply chain, the aim of which is to reduce inventory and costs and improve quality. The next section explores quality management within the supply chain.

2.4.4.4 Quality management within the supply chain

One of the aims of supply chain management is the improvement of the quality of the products delivered to the customer. A technique that is used in supply chain management to ensure the quality of the finished goods is Total Quality Management (TQM). TQM, according to the American Society for Quality (Wisner *et al.*, 2005:219), is defined as follows:

> *"Quality is defined by the customer through his/her satisfaction."*

TQM is an enterprise-wide philosophy, which includes suppliers and customers, and is closely linked to JIT. Using TQM, an enterprise strives for excellence (zero defects), by understanding, meeting and exceeding the customer's expectations (Wisner *et al.*, 2005).

TQM is based on two elements, namely, **focus on the customer**, which looks at the delivery of quality components and assemblies internally in the firm and the delivery of the final product to the customer; and **workforce involvement** from top management through to the lowest level employee, which, as with JIT, allows the workforce to come forward with proposals for improvements. The workforce is empowered to make decisions to solve any problems which will ultimately lead to better quality and customer satisfaction. Owing to this empowerment and further training, the workforce is much less inclined to leave the firm. TQM emphasises teamwork in structured problem solving (Hugo *et al.*, 2004 and Wisner *et al.*, 2005).

There are several approaches to TQM in a company and the supply chain. A few will be discussed briefly. For more detailed discussions of these approaches, the reader is referred to Hugo *et al.*, 2004 and Wisner *et al.*, 2005. These approaches to TQM are:

- **Six Sigma**: This is a quality management approach that relies heavily on statistical processes. The aim of Six Sigma is to keep the quality consistent within six standard deviations from the mean. Apart from using statistical tools, Six Sigma also uses management and quality assurance tools with the aim of eliminating variances in production that could affect the quality of the final product as well as ensuring improved customer satisfaction. Hugo *et al.* (2004:171) list the following six ways to improve the quality of the final product:

    - Genuine focus on the customer.
    - Data- and fact-driven management.
    - Process focus, management improvement.

    - Proactive management.
    - Boundary-less collaboration.
    - Drive for perfection; tolerance for failure.

- **Deming's way**: Managers are responsible for seeing that things happen. Thus the managers are responsible for the problems in the organisation. This means that they must also correct these problems. The managers can employ different methods such as the application of the right tools, encouragement, managerial and worker commitment and cultural change in the organisation. Deming lists 14 points for management to ensure quality. This approach also uses statistics to assist in TQM. Deming's 14 points for management are (Wisner *et al.*, 2005:221):

    - Create consistency of purpose toward improvement of product and service.
    - Adopt the new philosophy.
    - Cease dependence on inspection to improve quality.
    - End the practice of awarding business on the basis of price.
    - Constantly improve the production and service system.
    - Institute training on the job.
    - Institute leadership.
    - Drive out fear, so that everyone may work effectively.
    - Break down barriers between departments.
    - Eliminate slogans, exhortations and targets for the workforce.
    - Eliminate quotas and MBO and substitute leadership.
    - Remove barriers to pride of workmanship.
    - Institute a vigorous programme of education and self-improvement.
    - Put everyone to work to accomplish the transformation.

- **Crosby's way**: This is similar to Deming's; it uses four absolutes of quality, which are (Wisner *et al.*, 2005:222):

    - The definition of quality is conformance to requirements.

- The system of quality is prevention.
- The performance standard is zero defects.
- The measure of quality is the price of non-conformance.

Crosby then developed 14 steps to quality improvement. A combination of management activities and statistical analysis are used to achieve improved quality over time. The 14 steps are (Wisner *et al.*, 2005:222):

- Management commitment.
- The quality improvement team.
- Measurement.
- The cost of quality.
- Quality awareness.
- Corrective action.
- Zero defects (ZD) planning.
- Employee education.
- ZD day.
- Goal setting.
- Error-cause removal.
- Recognition.
- Quality councils.
- Repetition.

- **Juran's way**: Juran advocated that quality could be improved by bringing in change within the existing system, showing managers the cost of poor quality and using statistical control methods to show the workforce the effect of poor quality. Juran developed what he called his Quality Trilogy. The first part is quality planning, which means that if quality is to be improved, the strategy has to be planned. The second part is quality control by determining what to control, putting the measures in place to determine quality, and taking action where necessary. The third part of the trilogy is quality improvement by determining processes that make things even better than they are.

- **The Malcolm Baldridge National Quality Award**: This award is a United States (US) legal requirement, which encourages US firms to improve the quality of finished goods. It gives awards, based on a set of criteria, to participating firms which excel in quality. The award has seven categories for evaluating a firm. These categories are (Wisner *et al.*, 2005:224):

    - Leadership.
    - Strategic planning.
    - Customer and market focus.
    - Information and analysis.
    - Human resource focus.
    - Process management.
    - Business results.

- **International standards: ISO** – The International Organisation for Standardisation (ISO) was established in 1947 and has currently over 140 member countries. The aim of the organisation is to have a set of standards for industry to comply with, to ensure that products and processes are of an acceptable standard for use by the end customer. To ensure the quality of the commodities traded, the ISO developed the ISO 9000 quality system. Companies have to be ISO 9000 certified to do business, especially in European Union countries and the US. There are three documents that are essential doing business competitively, namely:

    - ISO 9000:2000 – The fundamentals and vocabulary necessary to establish the requirements for quality management.
    - ISO 9001:2000 – The documentation of activities to create a product.
    - ISO 9004:2000 – An extension of ISO 9001:2000 to increase the benefits to all the parties who are linked to, or affected by, an organisation.

ISO has eight quality management principles to ensure the quality of products delivered. These principles are (Hugo *et al.*, 2004 and Wisner *et al.*, 2005):

- o Customer focus.
- o Leadership.
- o Involvement of people.
- o Process approach.
- o System approach to management.
- o Continual improvement.
- o Factual approach to decision-making
- o Mutually beneficial supplier relationships.

The different approaches to achieve TQM have been explored in the above paragraphs. The approaches have two main elements in common, namely customer focus and workforce involvement ranging from management to the lowest level employee. The next part briefly examines several tools that can be employed to implement and run TQM. Wisner *et al.* (2005) list the following tools:

- Flow diagrams: Used to map the flow of a manufacturing or service process. Once the process is mapped, problem areas can be identified and corrected.
- Check charts: Used to show the frequency of problems that occur during a process based on a list of possible problems that can occur. Once these problems have been identified after analysing the data, they can be remedied.
- Pareto charts: Used to rank existing problems from the greatest to the least impact based on the Pareto principle. Problems with the greatest impact are solved first.
- Cause-and-effect diagrams: The alternative name is fishbone diagrams. These diagrams show the causes and effects of a problem. The problem is listed at the front of the diagram, with the four main causes of the

problem. The four main causes are: manpower, machinery, methods and materials. The sub-causes of each main cause are then listed. The aim is to "kill the fish", i.e. to solve the problem based on the causes (Bolstorff and Rosenbaum, 2003). To be effective, the analysis should include everybody involved in the process for which problem analysis is done.

- Statistical process control: Used to monitor performance visually and to compare the performance to desired levels or standards. (The reader is referred to Wisner *et al.* (2005:229-236) for a detailed discussion and methods of statistical process control.)

This section has discussed operational issues in the supply chain ranging from forecasting, operations planning to quality management. Under forecasting, the customer's future needs are determined which will in turn influence the production. To enable production, operational planning has to be done. Operations are planned based on three time horizons, namely long-, medium- and short-term horizons, known as the aggregate production plan which guides the master production schedule, and which in turn guides the materials requirement plan. Production must be quality controlled and the method used is total quality management. To enable the firm to utilise these operational methods to the full, it needs to do marketing. Marketing is based on the customer's needs as forecast, but marketing goes beyond that since it influences the supply chain, the kind of suppliers needed to fulfil the materials requirement plan, the quality of the product and customer satisfaction. Marketing is examined in more detail in the next section.

2.4.5 Marketing

Marketing must be in place to enable the product to be delivered to the customer based on the results of the forecast. In this research, marketing is discussed according to Min (2001), who sees marketing in a broad context as a form of business philosophy which includes the establishment of supply chain partnerships to create an efficient and effective supply chain that will deliver on customer expectations. Marketing, according to the American Marketing Association as quoted in Min (2001:79), is defined as follows:

"Marketing is the process of planning and executing the conception, pricing, promotion and distribution of ideas, goods and services to create exchanges that satisfy individual and organisational goals."

The exchange mentioned in this definition occurs within a market. A market is defined as a collection of buyers and sellers who interact with each other and where an exchange can occur based on certain conditions that are met (Min, 2001). Min (2001) breaks marketing into three categories: the first influences the second, the second the third and each category influences how the supply chain is managed, namely:

- Marketing concept.
- Market orientation.
- Relationship marketing.

The marketing concept according to Min (2001) is a business philosophy that guides market orientation. This philosophy integrates and coordinates a firm's activities and processes from marketing and production to delivery of the final product to the customer, based on the customer's need. The aim is to sustain the firm's long-term profitability (Min, 2001). The marketing concept is based on three pillars, namely:

- Customer focus: To determine and respond to the customer's need as determined by the forecast or input from the customer-supplier relationship.
- Coordinated marketing: Coordinated marketing is achieved within the firm between the marketing department and the workforces of the other departments that have contact with the client (seen as part-time marketers). To maximise profitability, coordinated marketing also depends on inter-firm coordination to respond effectively to the customer's need.
- Profitability: The main aim is to keep the marketing cost as low as possible and sales as high as possible (Min, 2001 and Mentzer, 2004).

In short, the marketing concepts guide the firm on how to satisfy the customer in a coordinated manner to maximise profit. The marketing concept is a basic set of rules and beliefs that has the customer as its focus, which lays the foundation of the market orientation of the firm. Market orientation guides the supply chain relationships between the firm and its suppliers and customers. This is known as relationship marketing. The combination of both marketing orientation and relationship marketing assist supply chain management to guide the supply chain to its common goal, which is the achievement of customer satisfaction at a profit (Min, 2001).

Market orientation is the implementation of the marketing concepts and consists of three activities:

- Generation: This is the creation of market intelligence based on data collected from customers who are linked in partnership with the supplier. Methods are used such as point-of-sale (POS) data or electronic data interchange (EDI), and forecasts are made to determine future customer needs. Forecasting is discussed in Section 2.4.4.2. Lee and Whang (2004) and Mentzer (2004) mention that the generation of market intelligence can be outsourced to companies that have access to industry-wide data and can generate intelligence to their customers using sophisticated analytical processes.
- Dissemination: Once the market intelligence has been created it needs to be disseminated within the firm and the supply chain partners.
- Responsiveness: On receiving the disseminated market intelligence, the firm has to respond. This is done via the aggregated production plan, the master production schedule, the materials requirement plan, related resources management and total quality management. Responsiveness is also achieved through the behaviour of the workers who should be influenced to maintain a customer orientation, a competitor orientation and inter-functional coordination (Min, 2001).

The above activities lead a firm to determine what Christopher (1998) refers to as the right product at the right price, using the correct promotion of the product and the right place to which the product needs to be delivered. All these activities must be managed correctly by the managers within the organisation to ensure the active participation of all the firm's workforce and to guarantee the firm's success (Min, 2001 and Mentzer, 2004). The method of Collaborative Planning, Forecasting and Replenishment (CPFR) is one of the tools that can be utilised for carrying out the above activities. See Section 2.4.2.2 for a more in-depth discussion on CPFR. Market orientation impacts the firm and the supply chain in the following ways (Min, 2001):

- *How the firm is managed*: Market orientation unifies the focus of the firm and its supply chain partners in collecting market information and utilises this information to deliver superior customer value on a continuous basis. This focus also encourages the firm and its supply chain partners to rise to higher levels of performance and quality at reduced cost to the supply chain as a whole.
- *Redefinition of the roles within a firm and its supply chain partners*: Market orientation forces the firm and its supply chain partners to redefine roles within each function in the firm and its supply chain partners to ensure that the customer's expectations are met and exceeded through the coordination of all the supply chain activities. This is achieved by making everybody within the supply chain a marketer, whether full time or part time. Full-time marketers are those employees whose responsibility is to market the products. Part-time marketers are those employees responsible for other activities in the supply chain but who also have contact with the customer. An example of marketing activity of a part-time marketer is to show a high level of professionalism when interacting with a customer.
- *Restructuring of the organisation's system*: Owing to the aim of customer satisfaction, different departments become inter-functionally interlinked, thus causing the boundaries between the different departments to be less defined if they are to achieve and exceed expectations. Kohler (1997, as

referenced in Min, 2001) proposes, based on the blurring of boundaries, that business processes should be managed rather than managing departments to create efficient and effective responses to achieve and exceed customer satisfaction. Christopher (1998) is of the opinion that the marketing department and the other departments within a firm must work together to enable the firm and its supply chain partners to be effective and efficient.

- *Market orientation leads to superior business performance*. The combination of the above three approaches forces the firm to deliver superior business performance, which results in financial improvement, workforce commitment, improved sales, bigger market share, growth and high levels of customer satisfaction.

Market orientation as mentioned above includes the firm and its supply chain partners upstream and downstream (customers and suppliers). To enable the firm to build good relationships with its supply chain partners, these relationships must be managed using relationship marketing which is guided by the market orientation. The relationships between supply chain partners start with the development of trust based on shared norms and commitments. Trust is necessary to enable the exchange of information and open communication between partners, and the ability to respond jointly to customer needs (Christopher, 1998, Handfield and Nichols, 1999, Min, 2001, Roberts, 2003 and Wisner *et al.*, 2005). Relationship marketing enables the supply chain partners to institute close long-term relationships and benchmarking and performance measurements, and to pursue strategic alliances with new partners (Min, 2001).

Min (2001:91) defines relationship marketing as that which "*pursues buyer-seller partnerships, strategic alliances, joint ventures and networks, all of which assume total-dependence relationships.*" He lists the following requirements for instituting relationship marketing:

- Trust between partners as mentioned in the previous paragraphs.

- Mutual benefit: the benefits within the relationship are bigger than the benefits for each individual member alone.
- Financial benefits and competitive advantage will accrue if the firm forms close relationships with its customers. This can lead to vendor-managed inventory (Roberts, 2003) and/or the placement of a supplier employee at the customer who acts as a buyer for the customer.
- Service guarantees and two-way communications between supplier and buyer that entrench speedy response to customer needs and on-time delivery of goods.
- Cooperation between the firm's marketing and operations functions, operations guided by marketing based on marketing's close relationship with the customer.
- Internal marketing of the firm to align the complete workforce (managers and workers) to be part-time marketers through direct or indirect actions. Actions could include training, skills, commitment and motivation.

Once these requirements are in place, relationship marketing will impact on the management of the firm. It promotes inter-functional coordination so as to respond more efficiently and effectively to customers' needs. To enable this inter-functional coordination, the firm must redefine the responsibilities of each function, where workforce members, who interact with clients, act as part-time marketers per the above requirement. This must be managed properly to ensure its success. The change in approach as guided by relationship marketing causes the boundaries between different functions to become blurred as stated above. The firm's marketing effectiveness improves owing to the close and long-term relationship that it develops with its customers, which allows the customers to be involved in the manufacturing process, and which will ensure commitment to the customer of goods of expected quality and the timely delivery. Relationship marketing also guides the firm as to when to bring in and manage outside resources to improve its ability to meet demand. Outside resources could be third-party logistics service providers employed to enhance the distribution of finished goods to the customers. Relationship marketing lowers the risk both to the seller and the customer. The seller is assured of market, and the customer has the assurance of receiving stock on time. There is also a low risk of stock-outs. All the above aspects impact on the management of the firm, and the result will be lower marketing costs owing to the long-term relationships, which in turn translate into financial benefits. Relationship marketing guides the establishment, maintenance and enhancement of supply chain relationships with the firm's suppliers and customers to achieve mutually agreed upon supply chain goals. Hugo *et al.* (2005) give a detailed discussion on how to establish these partnerships from the selection process, to the establishment of strategic supplier partnerships and alliances, to the management of these relationships. The long-term relationships among the firm and its suppliers and customers are beneficial for supply chain management so as to ensure an efficient and effective supply chain for the benefit of all the supply chain members (Min, 2001 and Mentzer, 2004).

Figure 2.1 gives a schematic overview of the interaction between the marketing concept, marketing orientation, relationship marketing and supply chain management which will lead the supply chain to a differential advantage over its competitors.

Marketing is used to determine what will be produced to satisfy customer needs. Three steps are used to determine the supply chain partners. The first step is the marketing concept, which is a business philosophy which has customer satisfaction as its goal and guides the market orientation. Market orientation gives the direction of the firm with respect to satisfying the customer's need. This direction guides the relationship marketing with respect to the selection of supply chain partners as well as the incorporation of outside resources to enable the firm and the supply chain to respond efficiently and effectively to customer needs. An outside resource that is used by industry is third party logistics (3PL) service providers. 3PL service providers provide all or some of the firm's or supply chain members' logistics services and are discussed in the next section.

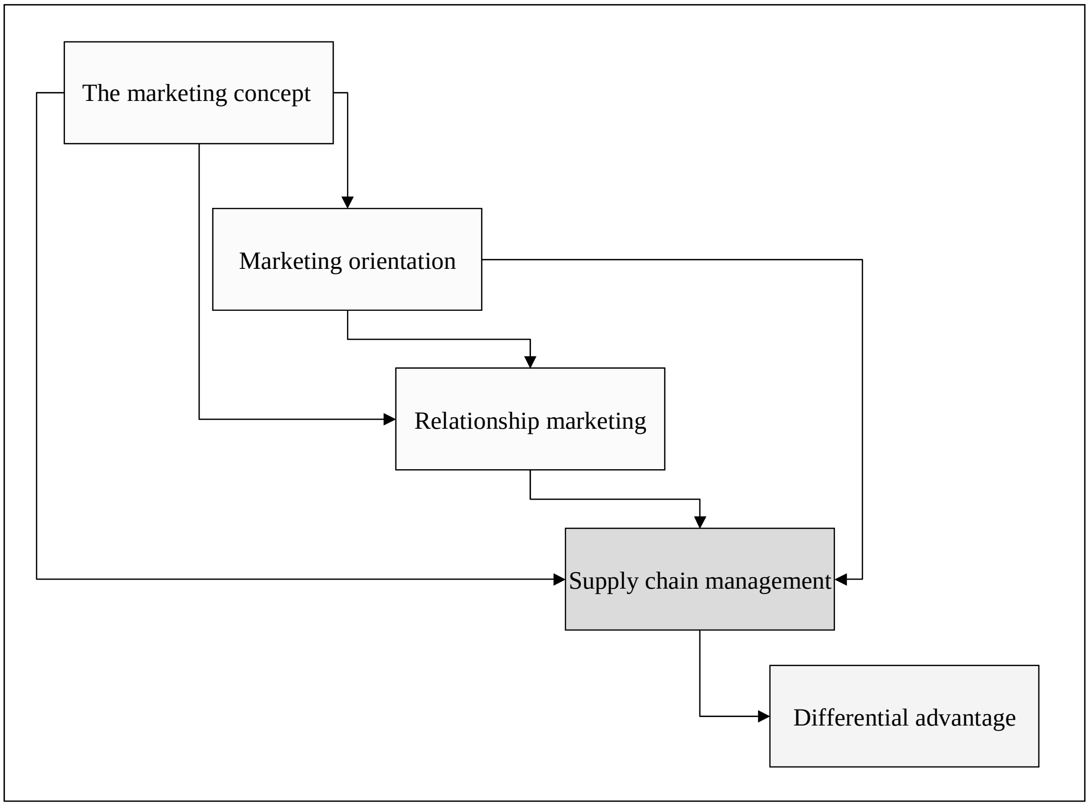

Figure 2.1: The integration of marketing to ensure a differential advantage
(from Min, 2001:97, Figure 4.4)

2.4.6 Third-party logistics

Third-party logistics (3PL) service providers as referred to in Sections 2.4.2.4 and 2.4.5 are external organisations contracted by organisations or firms to take care of the organisation's or the firm's logistics activities. Organisations outsource their complete logistics activities or only part of their logistics activities such as sourcing, materials management, transportation and distribution. Outsourcing allows organisations and their supply chain members to concentrate on their core activities to maximise efficiency, effectiveness and profits. 3PLs, through their expertise and economy of scale, can provide logistics services more efficiently and at lower cost than the organisation's own in-house logistics activities. 3PLs also provide supply chain management services (Hugo *et al*., 2004 and Wisner *et al.*, 2005). 3PLs form part of the ultimate supply chain as proposed by Mentzer *et al.*, 2001 (see Figure 1.3).

Hugo *et al*., 2004 and Wisner *et al.*, 2005 list the following reasons to outsource logistics activities (or some of them) to 3PLs:

- Outsourcing allows the firm and supply chain members to concentrate on their core activities.
- Reduction in inventory.
- 3PLs allow better market penetration owing to their comprehensive logistics network.
- Single point of entry.
- 3PLs allow global supply chains to be implemented and operated.
- 3PLs are specialists in logistics.
- 3PLs offer flexibility.
- Partial outsourcing can lead an organisation to gain leadership with respect to logistics costs and value.
- 3PLs provide supply chain management services.
- They provide vendor-managed inventory services.
- Recently 3PLs have also begun to offer purchasing services, especially of less strategic items, which allows the organisation to concentrate on strategic purchases only.

When an organisation contracts a 3PL service provider, it enters into a relationship with the 3PL. Such relationships vary. If it is a long-term relationship, the 3PL must have a high level of commitment to the organisation. The scope of this relationship can be narrow, i.e. it is limited to certain activities only, or it can be broad and encompass a wide range of activities along the whole supply chain. Some organisations have a mixed relationship with a 3PL, i.e. the organisation carries out certain logistics activities itself, while the other logistics activities are provided by the 3PL (Hugo *et al*., 2004). Hugo *et al*. (2004) indicate that the most outsourced activities to a 3PL are transport, warehousing, fleet management and shipment consolidation. Other activities offered by a 3PL include, but are not limited to, freight and bill auditing and payment, inventory, packaging and final assembly as well as freight forwarding (Hugo *et al*., 2004).

When organisations investigate the option of outsourcing their logistics activities to a 3PL, the 3PL has to meet, according to Hugo *et al*. (2004), the following three criteria:

- The level of service provided.
- The quality of the people.
- Costs.

Wisner *et al.* (2005) further indicate that once a 3PL has been selected, the contracting organisation should monitor the performance of the 3PL using agreed-upon performance criteria. Hugo *et al*. (2004:62) give the following possible impacts on both the organisation and the 3PL:

- The selection of a 3PL will impact on the organisation's resources, employees and customers, such as the selling off of vehicles and the redundancy of its drivers, and the customers now having to deal with the 3PL regarding delivery of goods.
- The impact is considerable for customers, especially when there has been a long-term relationship with the supplier as is usual with a successful supply chain management. The authors recommend that the customer should be involved in the selection of a 3PL.
- Retraining and re-deployment of staff may be necessary.
- The 3PL has to learn the organisation's culture to ensure long-term relationships.
- The 3PL will mostly be in a strategic partnership with the organisation.

Andersen Consulting argues that organisations need several 3PLs to provide all the needs of the organisation as 3PLs cannot deliver a full service. They further argue that service levels of 3PLs decline over time, and that labour issues within a contracted 3PL can cause costly problems for the organisation. To provide a solution to their arguments, Andersen Consulting developed a 4PL (a trademark of Andersen Consulting) which acts as a broker between the organisation and several 3PLs, thus providing a full suite of logistics services (Hugo *et al*., 2004).

Outsourcing of all or part of the logistics activities of an organisation to a 3PL or 4PL has its advantages as mentioned above, but Wisner *et al.* (2005:100) list the following possible disadvantages:

- The organisation can experience a loss of control over its logistics activities.
- Loss of communication between supplier and customer, which can impact on the supplier's response to its customer needs.
- The potential spread of confidential information to customers and suppliers.
- The potential damage to the firm or organisation's reputation if mistakes are made by the 3PL providers (4PL tries to address and minimise this disadvantage).
- The potential loss of important supplier alliances.

This section has given an overview on what 3PLs can offer, ranging from a few logistics activities to full logistics and supply chain management services. One of the advantages that a 3PL can offer to an organisation is access to global supply chains, based on the 3PL's extensive logistics network. Global supply chains are discussed next.

2.4.7 Global supply chains

2.4.7.1 Introduction

In the 1990s, industries opened up to the world, which resulted in global trade and integration as well as the establishment of global firms such as McDonalds, SAB Miller and Toyota. With this expansion it was necessary to establish global supply chains to ensure competitiveness and profitability. Global supply chains should be as simple and efficient as possible (Christopher, 1998 and Hugo *et al*., 2004). Toyota developed a global Just-in-Time (JIT) method for its global operations (Roberts, 2003). Mentzer (2004) states that some global firms have their research and development (R&D) with highly skilled professionals in one country and their production in one or more countries that have more favourable labour conditions. Nike is an example, where its R&D is in the USA and its production facilities in several Asian countries. This section looks into global supply chains, advantages, possible challenges and the steps to implement such a supply chain.

2.4.7.2 Overview of globalisation and global trade

Globalisation is the result of the customer's needs which are becoming more sophisticated and demanding throughout the world. If firms are to stay competitive and profitable, they need to ensure that new products and services reach the customer as quickly as possible, more efficiently, and at a lower cost than that offered by their competitors (Christopher, 1998 and Hugo *et al*., 2004). A definition of globalisation given by Govindarajan and Gupta 1999:5 as quoted in Hugo *et al*. (2004) is:

> *"The growing interdependence among countries, which is reflected in increasing cross-border flow of goods, services, capital and know-how."*

Globalisation also indicates that interdependence among countries includes the interdependence of the results of calamities occurring in other countries. Examples are the Asian economic crises in the mid-1990s, Middle-Eastern instability, and the impact of Hurricane Katrina on the global oil price. There are pressure groups, local and international, which are concerned that globalisation is happening too quickly and that the developed countries are actually exploiting the developing countries with negative results to these countries. The negative results are increased job losses, such as in the South African textile industry, which in turn leads to increased poverty (Hugo *et al*., 2004).

Firms cannot at present survive on a domestic market alone, as global firms compete against them by offering the same product at a lower price, thus forcing these firms also to compete at a global level. To regulate global trade, the World Trade Organisation (WTO) was established in 1994 to set and enforce fair trading rules for global trade. It currently has 136 member countries including South

Africa and China. The aim of the WTO is to make cross-border trade easier and it has achieved much in this respect. The biggest challenge currently facing the WTO is the liberalisation of agricultural trade which the developing world sees as their starting block for sustainable development (Hugo *et al*., 2004).

The success of global firms in most of the regions of the world where they operate is, according to Hugo *et al*. (2004:326), based on the:

- Global and regional sourcing of materials.
- Strategic positioning of distribution centres and operations.
- Establishment of regional production operations.
- Development of lean logistics networks.
- Implementation of real-time information networks.

2.4.7.3 Creation of regional trading blocks

One of the results of globalisation has been the creation of regional trade blocks such as the European Union (EU), the Indian Ocean Rim Association for Regional Cooperation (IOR-ARC), the Asia-Pacific Economic Cooperation (APEC), and the Southern African Development Community (SADC). There are two different types of trading blocks. The first is based on free trade agreements, which allow the expansion of market opportunities in member countries. Free trade agreements between South Africa and the EU and the USA, as well as between the SADC member countries, are examples of the first type of trading block. Free trade agreements allow lowering of costs because of lower transport and operating costs and the lowering or phased elimination of tariffs between member countries. This leads to the simplification of supply chains. Free trade agreements lay down certain rules and regulations that needs to be complied with in order to qualify for the agreed upon benefits (Nix, 2001; Roberts, 2003 and Hugo *et al*., 2004). The second type of trading block is an economic union, which is much more complex and sophisticated in nature in comparison to free trade agreements. Economic unions may have a parliament, a judiciary, a central bank and a common currency. The EU is an example of such an economic union. The African Union is based on similar principles and has a parliament in place (Hugo *et al*., 2004). The objectives of an economic union, according to Hugo *et al*. (2004:328), are to:

- Eradicate trade restrictions.
- Establish social and political protocols.
- Establish common monetary and fiscal policies.
- Create a common market and a single currency.
- Develop a borderless environment.

2.4.7.4 Global supply chains: implementation, management and risks

Global supply chains are more difficult to manage than their domestic counterparts owing to unique problems that arise from the complexity of these chains. The complexities are the result of global supply chains having to negotiate trade regulations and barriers, channel intermediaries such as clearing agents, import and distribution agents, single service providers and global logistics service providers (3PL and 4PL), documentation and diversity in trading cultures and customs as well as incompatible information systems. Global supply chains are also at risk from natural and human factors, which adds to the complexity of the chain (Hugo *et al*., 2004).

Harrison (2004b:8) states that to implement a global supply chain, a firm has to collect several types of data:

- Locational data, which includes the physical location of the entity or entities, information regarding trading blocks in which the facility or facilities occur, and social and cultural customs.
- Process data, which describes the facility's capability to add value to the chain such as manufacturing, transportation and retail capabilities and service.
- Product data such as the different types of stock-keeping units and their attributes, bill of materials requirements and structure.

- Movements data, which give a detailed view of the logistics network such as the description, capability and cost of a transportation link between locations.

Hugo *et al*. (2004) explain that the global supply chain implementation process consists of four phases, namely:

1. Analysing the global market to understand the uncontrollable and controllable elements. Uncontrollable elements are those elements characterised by uncertainty, volatility and rapid changes (Hugo et al., 2004:330). They include the legal and political systems of countries in which the markets will be located, regional and global economic conditions (an example was the Asian Tigers economic crisis in mid 1990's), competitive forces, and social and cultural customs. Firms that operate in these uncontrollable environments have no means of controlling these elements and thus have to have contingencies in place to counter any unfortunate eventualities. Hugo *et al*. (2004:332) list the following controllable elements within a global supply chain over which a firm has an influence:

- Inventory.
- Transportation.
- Costs.
- Warehousing.
- Customer service.
- Packaging.
- Materials handling.
- Information.
- Lead time and end-to-end pipeline time.

2. The second phase, after the analysis of the global market, is to design the supply chain and formulate global logistics strategies. These are customer service strategies which include: perfect order fulfilment, rapid product introduction and quick response using lean logistics and e-commerce; distribution

channel strategies through 3PLs and 4PLs; the centralisation of inventory such as the use of regional distribution centres close to the customer in conjunction with well-established information technology systems; focused factories that deliver a limited range and mix of products suited for the local market; and postponement, where the final product is assembled only once the final requirement is known (Christopher, 1998; Roberts, 2003; Hugo *et al*., 2004 and Mentzer, 2004). Postponement strategies are bundled manufacturing, unicentric postponement, deferred assembly and deferred packaging and labelling (Hugo *et al*., 2004:335).

3. The implementation and management of the global supply chain is the third phase of establishing and maintaining a global supply chain. Hugo *et al*. (2004:335) argue that the following factors must be taken into account when implementing and maintaining a global supply chain:

- *Lead times and end-to-end pipeline times* need to be kept to a minimum in order to save costs. This can be achieved by establishing effective partnerships between supplier and customers through the use of information technology such as e-commerce, electronic data interchange (EDI), the Internet, and improved global transportation. Christopher (1998) mentions that there is a move to use airfreight more often to move goods than in the past owing to better cargo handling by airlines.
- *Transit times* can be shortened by reducing the number of handling points within the supply chain, the use of door-to-door delivery systems and the use of 3PL and 4PL service providers.
- *Consolidation and break bulk alternative.* The problem is where and when consolidation or break bulk should be done. Consolidation is the consolidation of shipments from various suppliers to one customer at a specific location and then shipped in bulk to the customer. Break bulk is where the shipment from one supplier is split into smaller components destined for different customers. Consolidation is normally done at the source and break bulk is done close to the customer (Christopher, 1998).

- *Transportation decision-making* is the process of deciding which transportation mode or modes that are the most cost effective should be utilised to ship the consignment to the customer. Transportation modes are sea, road, air and rail. If more than one mode of transportation is used, it is known as a modal split. Containers, for example, can be transported using a modal split between a truck and rail (land) and a container ship (sea) from supplier to customer.
- *Completely knocked-down (CKD) or completely built-up (CBU) form?* Products in CKD form have the advantage that they can be shipped in higher numbers per volume than CBU products. Some 3PLs and 4PLs offer final assembly services, thus bringing the final assembly of the product closer to the customer. In other instances firms deliver the product in CKD form to the customer, where the customer does the final assembly. An example is bookshelves in CKD form, with all the necessary parts for assembly (including a manual) that can be bought in major department stores for home assembly. Hewlett Packard ships their plotters in semi-CKD form to their customers, and the agent assembles the plotter at the customer's premises. CKD form is an effective cost saver in terms of labour and transport.
- *Global information management* is employed to consolidate flows within the supply chain, and reduce handling points within the supply chain. Decision-making tools are used for transportation planning, data are analysed for performance measurements, supply chain visibility and the flow of real-time information, enterprise resource planning systems such as Oracle and SAP are established, and electronic documentation ranging from procurement to invoicing and statements is used.
- *Documentation to allow cross-border movement and legal requirements compliance* – this includes sales contracts, certificates of origin (COO), export declarations, bills of lading and letters of credit.
- *Free trade zones* that benefit firms trading abroad. *Bonded warehousing* can incur unnecessary costs for suppliers when goods are exported to countries with bonded warehouses.

4. The last step in the global supply chain process is the performance measurement of the cost effectiveness and efficiency of the global supply chain. Some aspects of performance measurement were discussed under quality in the supply chain in Section 2.4.4.4. Wisner *et al.* (2005) give a detailed explanation of performance measurement. The Supply-Chain Operations Reference (SCOR) model is one of the recognised methods of supply chain performance measurement (Wisner *et al.*, 2005).

Risks are involved when operating a global supply chain, and these risks need to be managed. The most common risks to a global supply chain are: exchange rate fluctuations, which can cause countries that are import oriented (i.e. buying your goods) to become export oriented; payment risks, which could be linked to exchange rate fluctuations where the customer budgeted a certain amount at a specific exchange rate and now has to pay more in local currency owing to the deterioration of the exchange rate and so cannot honour the payment owing to money shortage and defaults on the payment; and changes in market structures and conditions caused by changes in customer demand, sudden political instability or changed labour conditions or a combination thereof.

A simple management strategy or combination of three different risk management strategies can be used to manage the above risks. The first strategy is the speculative strategy, where the global firm assumes that specific conditions in target countries will allow good results, but this can have disastrous effects on the firm if these conditions should change. Global firms mostly avoid this management strategy. The second is the hedge strategy, which is designed to safeguard a firm against problems in one or more parts of the global supply chain. If a problem occurs in one part of the supply chain, it can be offset by another part of the supply chain with similar functions. Some firms have production facilities for the same type of product in different countries. The automobile industry is an example such global entities. The third strategy, the flexible strategy, is to develop several different strategies based on scenarios to protect a firm. These flexible strategies can be quickly reconfigured to meet any new demands on the global supply chain. An example is to have a lean operation in one country and, where the same product is made, a small excess stock in another country to cope with a large surge in demand in the "lean" country (Roberts, 2003 and Hugo *et al*., 2004).

This section has dealt with the global supply chain, starting with an overview of globalisation, global trade and why it is important to establish a global supply chain, as well as the role of regional trading blocks. The global supply chain process consists of four distinct phases, namely: the analysis of data, the design of the global supply chain based on the results of the analyses, the implementation and management of the chain, and lastly, performance measurement of the global supply chain. All these phases rely on information and a brief overview has been given of the types of data needed. For the collection, analysis and monitoring of the different data, the supply chain relies on different information technologies and infrastructures. The next section gives an overview of the role of information and communication technology in the supply chain.

2.4.8 The role of information and communications technology (ICT) in supply chains

2.4.8.1 Introduction

Section 2.4 discusses several aspects of supply chains and supply chain management, namely the logistics of order processing, inventory, transportation and warehousing; materials management; supply chain operations including forecasting, operations planning and quality management; marketing; and the importance of third and fourth-party logistics and global supply chains. All these aspects have one thing in common, namely reliance on information. The following definition of a supply chain given in Section 2.3 also indicates the importance of information within a supply chain. In this section an overview of information and ICT in supply chain is given and in the second part of the section examples are shown of ICT and systems that are used in the supply chain.

2.4.8.2 Information, information systems and ICT in supply chains

With the coming of the personal computer, optical fibre networks, the Internet and the World Wide Web, information systems and ICT have become affordable to firms in the supply chain. These systems and technologies have enabled such firms to save costs by reducing the information time delay of paper-based activities, which has resulted in quicker responses through the supply chain (Handfield and Nichols, 1999 and Roberts, 2003). The systems and technologies have also forced supply chain partners to coordinate their activities within the supply chain in order to achieve an effective and efficient supply chain. In other words, they have integrated the supply chain (Handfield and Nichols, 1999; Roberts, 2003 and Hugo *et al*., 2004).

Hugo *et al*. (2004) argue that information flow in a supply chain is both a logistics activity and an enabler of the supply chain. It is seen as a logistics activity since certain activities, hardware, software and infrastructure should be in place, coordinated and managed to facilitate the flow of information in the supply chain. This ensures that timely and critical information will flow up and down the supply chain to bring customer satisfaction, costs saving through the reduction of inventory and human resources to competitive levels. It also assists in strategic planning and resource deployment (Roberts, 2003). Handfield and Nichols (1999:6) suggest that supply chain information systems and technologies have or will have the following characteristics:

- Centralised coordination of information flows.
- Total logistics management – integration of all transportation, ordering and manufacturing systems.
- Order-change notices which trigger a cascading series of modifications to production schedules, logistics plans, and warehouse operations.
- Global visibility in transportation resources across business units and national boundaries.
- Global inventory management – the ability to locate every item and track its movement.

- Global sourcing – the consolidation of the purchasing function across organisational lines, facilitating purchasing leverage and component standardisation across business units.
- Inter-company information access – the clarity of production and demand information residing in organisations both upstream and downstream throughout the value chain.
- Data interchange between affiliates and non-affiliates through standard telecommunications channels.
- Data capture – the ability to acquire data regarding an order at the point of origin, and to track products during their movement and as their characteristics change, as well as to acquire point-of-sale data.
- Transformation of the business from within – managers who can see the "big picture" and accept new forms of business processes and systems.
- Improvements in supplier-customer relationships – to justify investments in technology linkages.
- Allowing electronic payments using electronic funds transfer (EFT) protocols.

These characteristics are present in electronic commerce (e-commerce), which uses the Internet as one of its underlying technologies. The Internet enables communication between organisations and between supply chain partners in particular. E-commerce is defined as follows (ACL 2002:2 as quoted in Hugo *et al*., 2004):

> *"A dynamic set of technologies, applications and management systems that enable and manage relationships between an enterprise, its functions and processes and those of its customers, suppliers, value chain, community and/or industry."*

There are two e-commerce activities. The first is between businesses and is known as B2B where all the inter-business activities are incorporated. The second e-commerce is between a business and its customer, known as B2C. An example of B2C e-commerce activity is on-line shopping over the Internet such as at Amazon.com and Kalahari.net. Supply chains are typical B2B activities with respect to e-commerce (Hugo *et al*., 2004). B2B e-commerce activities, based on the above definition, include but are not limited to the systems such as electronic data interchange (EDI), bar coding and scanning, data warehouses, Internet/Intranet/Extranet, decision-support systems, e-procurement, e-sourcing, e-purchasing, electronic fund transfer (EFT) and the like. These systems are discussed briefly in the next section (Handfield and Nichols, 1999 and Hugo *et al*., 2004). E-logistics, according to Hugo *et al*. (2004), is the use of the Internet, e-commerce and other systems to track, trace and control the movement of goods between supply chain partners or between a business and its consumers (B2C). E-logistics also helps with the planning of receiving goods such as the activation of the receiving processes to receive the goods and where to place the goods in the warehouse, as well as with planning of transportation modes for shipment, dates for commitment of goods to a customer and human resource planning with regard to receiving, storing and dispatching of goods (Hugo *et al*., 2004).

2.4.8.3 Information systems and technologies used in supply chains and e-commerce

This section briefly examines some of the important systems and technologies used in supply chains and e-commerce. These systems and technologies are:

Electronic data interchange (EDI) is briefly mentioned in Sections 2.4.4.3, 2.4.5, 2.4.7.5 and 2.4.8.2. EDI is, according to Handfield and Nichols (1999), the exchange of business documents between a computer in business A and another computer in business B. It is based on the willingness between supply chain partners to share information as well as the effective utilisation of the information to the benefit of the whole supply chain. Handfield and Nichols (1999:31) list some of the benefits of implementing EDI:

- Quick access to information.
- Better customer service.
- Reduced paperwork.

- Better communications.
- Increased productivity.
- Improved tracing and expediting.
- Cost efficiency.
- Competitive advantage.
- Improved billing.

EDI is an effective tool to support continuous replenishment programmes (CRP) also known as vendor-managed inventory (VMI) as briefly discussed in Section 2.4.1. Suppliers use EDI information from their downstream supply chain partners such as retailers to replenish their inventories. The downstream members' inventory is actually managed by their suppliers. Using EDI for this purpose, significant savings are made with regard to inventory reduction for both supplier and customer (downstream partners) (Handfield and Nichols, 1999). Hugo *et al*. (2004) mention that EDI was established before the advent of the Internet and relied on rigid and strict communication protocols to enable the exchange of data between organisations. It was the forerunner of e-commerce, which developed after the implementation of the Internet.

Bar coding and scanning – A bar code is a code on products and packages that can be read by a computer using a scanner. The bar codes are vertical black stripes of various thickness and number. Bar codes on packages are known as Universal Product Codes (UPC) that contain information on the product and manufacturer. UPC information is passed on to the customer or retailer and linked to a specific price and is read at the sales point. The point-of-sale data is then communicated through to the suppliers, who then have information on the customer's inventory level. When the inventory falls below a certain level, inventory replenishment is triggered. Other applications include part marking for assembly or the management of railway coaches in a shunting yard (Handfield and Nichols, 1999).

Data warehousing and decision-support systems – Data warehouses are seen as decision-support tools that have developed from business information systems, since they act as repositories of data from various sources. This allows the mining of data which are then used for decision-making. The data warehouse is structured around informational subjects rather than different business processes, which allows the extraction of information by various subscribers (Handfield and Nichols, 1999:33). Data mining allows the firm to explore, analyse, manage and present data in an easy-to-understand and use format. Data warehouses can be coupled to enterprise resource planning systems and other operational systems. Data marts are subsets of the data warehouse that serve a specific group within a firm, thus facilitating quicker access to information (Hugo *et al*., 2004). Decision-support systems are systems that assist decision-makers in the decision-making process using various technologies to store, extract and analyse data such as standard query language (SQL), expert system rules, scheduling algorithms, neural networks, linear programming, predictive modelling and demand management (Handfield and Nichols, 1999 and Hugo *et al*., 2004).

Internet, the World Wide Web, e-commerce and e-logistics – These are discussed in more detail in Section 2.4.8.2.

Sections 2.2 to 2.4 gave an in-depth description of supply chains and supply chain management: an historical overview of supply chains and supply chain management, the definitions and concepts of supply chains and supply chain management, logistics and materials management and operations within a supply chain. It also discussed the role of marketing, third and fourth-party logistics service providers and information and communication technologies within the supply chain and supply chain management as well as the global supply chain. The next section investigates a model for unpacking and understanding the supply chain as it is now, as well as modelling the supply chain as it should be together with supply chain management components. The Supply-Chain Operations Reference (SCOR) model from the Supply-Chain Council (2001) is such a model and is discussed briefly in the next section.

2.5 Supply-Chain Operations Reference Model (SCOR)

2.5.1 Introduction

The Supply-Chain Operations Reference (SCOR) model is a process model developed by the Supply-Chain Council, a not-for-profit US organisation. It is seen as a cross-industry standard for supply chain management. The model was first developed in 1996 by two companies, Pittiglio Rabin Todd & McGrath (PRTM) and AMR Research, together with 69 volunteer companies. SCOR's latest version is SCOR Version 7.0, which is extended to include retail supply chains (Supply-Chain Council, 2005). SCOR is a process reference model that contains standard descriptions of management processes; a framework of relationships amongst the standard processes; standard metrics to measure process performance; management practices that produce best-in-class performance; and standard alignment to features and functionality (Supply-Chain Council, 2005:2). Process reference models capture both the "as is" situation and the "to be" situation to which the company wants to progress based on actions to upgrade the "as is" to the "to be" state (Supply-Chain Council, 2005). It allows continuous improvement, which is part of the total quality management of a supply chain (see Section 2.4.4.4). Mentzer (2004) criticised the SCOR model, saying that supply chains are very individualistic and cannot be described by standard process descriptions. Wisner *et al.* (2005), however, mention the successful use of SCOR in companies such as Intel, IBM, 3M, Cisco, Siemens, Bayer and Mead Johnson Nutritionals, a division of Bristol-Myers Squibb. Based on these successful uses of the SCOR model in industry, it will be used to configure and analyse the GIS unit's supply chain to determine whether supply chain management can be utilised in the GIS environment and in the electronic information environment at large. The SCOR model is discussed in more detail in this section as the basis for this research.

2.5.2 SCOR model

The following boundary definition of the SCOR model is given by the Supply-Chain Council in which the model can be applied (Supply-Chain Council, 2005:3):

> *"From your supplier's supplier to your customer's customer."*

The range of SCOR is therefore from the supplier's supplier, the supplier, the firm (i.e. your company), the customer and the customer's customer (see Figure 2.2). Within that range SCOR looks at all the customer interactions, from order entry through to order payment via invoice; all the physical materials and service transactions from the firm's supplier's supplier to the firm's customer's customers, which includes equipment, supplies, spare parts, bulk products, software, etc.; and all the market interactions from the understanding of the aggregate demand to each order fulfilment.

2.5.2.1 The five SCOR process types plus ENABLE

As can be seen from Figure 2.2, SCOR consists of five management process types that describe the supply chain, namely PLAN, SOURCE, MAKE, DELIVER and RETURN for the supplier, the firm and the customer. The supplier's supplier and the customer's customer are only two management processes modelled, namely DELIVER and RETURN and SOURCE and RETURN. The supplier and customer can be either internal or external (Supply-Chain Council, 2005). An example of an internal supplier within the CSIR is the Satellite Applications Centre at Hartebeeshoek which provides satellite imagery to the GIS unit in the Natural Resources and the Environment (NRE) of the CSIR.

The supplier's supplier is the company which operates the satellite that acquires the imagery of the earth's surface, such as the Landsat TM from NASA. The internal client of the GIS unit in NRE is the unit within NRE which conducts an Environmental Impact Assessment (EIA) for a consulting engineering firm. The consulting engineering firm is then the customer's customer.

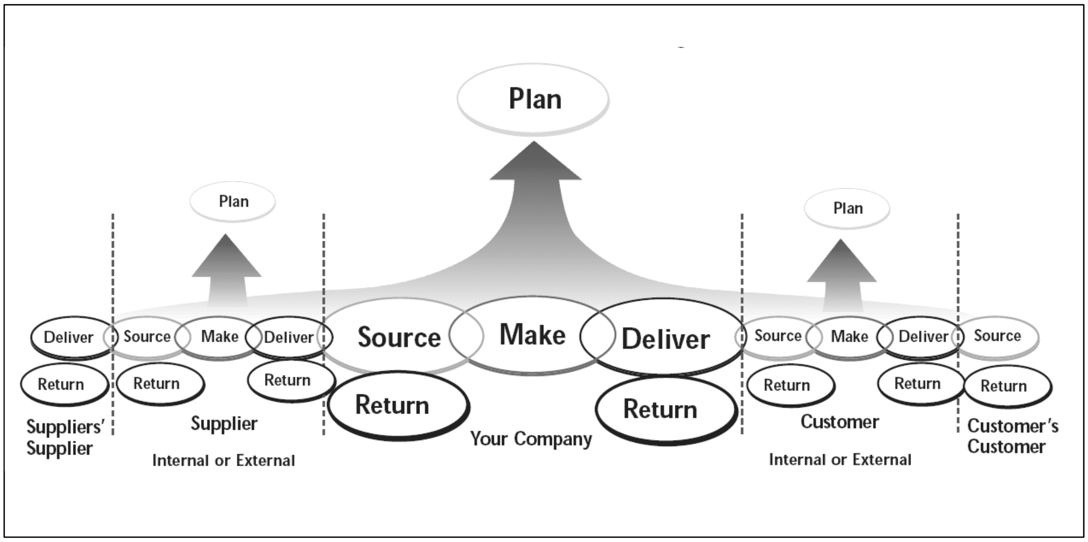

Figure 2.2: The five management processes of SCOR

(from: Supply-Chain Council, 2005:3)

PLAN looks at the demand/supply planning and management of the supply chain. Based on the market needs, PLAN balances the available resources with the requirements to produce the goods to satisfy the customer's need. It also communicates plans for the complete supply chain for the other four categories, namely RETURN, and the execution process categories SOURCE, MAKE and DELIVER. PLAN manages the business rules such as the development of supply chain performance standards (i.e. must achieve 90% perfect order fulfilment); supply chain performance measures to enable the set standards to be achieved; what data needs to be collected and how it will be collected; inventory needed for the manufacturing of the product (in the GIS context, spatial data are part of the inventory); capital assets required to manufacture the product such as GIS software, computers and plotters; transportation needed to receive the supplies and to deliver the product to the client, such as FTP to transfer large spatial data sets over the Internet; planning configuration which defines the establishment and the maintenance of information of a supply chain network of a similar type of product from the analysis of the market through to after-market support; and regulatory requirements and compliance such as the creation of metadata for each spatial data product. PLAN also aligns the supply chain unit plan with the financial plan of the firm (Supply-Chain Council, 2001 and 2005).

There are three types of product classes used in SCOR. The first class is the *stocked product*, which is a product that a firm manufactures and places in a warehouse and delivers when it is required by a customer. The amounts of stocked products are based on forecasts. A product catalogue which lists the available stocked products is used. From the GIS point of view, stocked products are electronic 1:50 000 scale maps that can be ordered from the Chief Directorate: Surveys and Mapping. The second class of product is a *make-to-order product*, which is where all the processes of manufacturing the product are in place, but the production is only activated when an order for the product is received. An example of a make-to-order product is georectified satellite imagery. The Satellite Applications Centre (SAC) at Hartebeeshoek downloads the satellite image but keeps it in raw data format. The SAC has standard procedures in place for georectification at various levels, depending on the need of the customer, and will only produce a georectified image when an order for such an image is placed. The third class of product is the *engineer-to-order product*. An engineer-to-order product is a product created to satisfy a customer's specific need. The creation of such a product includes design, manufacturing and delivery, and it is normally a once-off product. Most GIS projects will fall under this category (Supply-Chain Council, 2003).

SOURCE is concerned with the sourcing of raw materials and products from the firm's suppliers. There are three types of products that can be sourced from a supplier as discussed above: stocked products include raw materials, and make-to-order products and engineer-to-order products are delivered to the firm only once the firm triggers the order for these products. SOURCE looks at the following processes (Supply-Chain Council, 2005:4):

- *Schedule deliveries; receive, verify, and transfer product; and authorise supplier payments*. An example is the scheduling of the delivery of a georectified satellite image from the SAC; receiving the georectified image; verifying the image with regard to file format compatible with the GIS such as Erdas Imagine file format; metadata; required georectification level and area covered, and then transferring the image to the data warehouse; and once satisfied authorise payment to the SAC.

- *Identify and select supply sources when not predetermined, as for an engineer-to-order product*. There are GIS firms that produce GIS data that are unique to a specific client. An example is high-level and complex GIS modelling. The GIS unit then identifies the GIS firm that can satisfy its need and requests the engineer-to-order product.
- *Manage business rules, assess supplier performance, and maintain data*. Business rules are the rules which a GIS unit has to follow with respect to supplier selection. The unit's procurement rules are rules that must be followed when buying data, software, hardware and other products. If the GIS unit falls within a company, it is subject to the company's rules regarding procurement. Supplier performance includes delivery performance and the quality of the product received. Source data include information on suppliers, financials, and supplier performance and spend analysis, i.e. how many times the supplier was used in a financial year (Supply-Chain Council, 2003).
- *Manage inventory, capital assets, incoming product, supplier network, import/export requirements, and supplier agreements*. Inventory in a GIS unit is the spatial data in the data warehouse, paper and ink for the plotter, CD-ROMs, DVDs and other consumables needed for a specific project. Capital assets are the software and hardware that a GIS unit uses. Hardware used in a GIS unit consists of computers, plotters, data servers and digitising tablets to name a few. Other capital assets examples are the offices and office furniture used by the GIS unit. The management of the incoming product includes the reception, verification and transferring of the product into a data warehouse or office. Supplier networks are all the suppliers that the GIS unit uses to create a data product ranging from GIS firms that provide spatial data to the company that supplies the stationary to the unit.

MAKE looks at the production process of the firm. Three types of product are produced under MAKE, namely make-to-stock, make-to-order, and engineer-to-order. The following processes are part of MAKE, according to the Supply-Chain Council (2005:4):

- *Schedule production activities, issue product, produce and test, package, stage product and release product to deliver.* Under MAKE is where the GIS unit creates a GIS product. The GIS unit schedules the production activities for the GIS product, such as when the data are drawn from the data warehouse, and the types of data manipulation needed to create the final product. The term *issue product* for a GIS unit is the release of the spatial data (sourced and/or existing data) that will be used for the product from the data warehouse. The GIS unit then creates the GIS product and tests it, which includes quality control and the creation of metadata. The GIS product is then staged in the data warehouse from where it will be released for delivery. If the GIS product is sent on a CD-Rom or DVD, the product is released from the data warehouse, cut on the CD-ROM or DVD and packaged and then released for delivery. In the GIS context, packaging follows stage, not stage following packaging of the product.
- *Finalise engineering for engineer-to-order product*. In the context of spatial data analysis, this is the development and testing of the spatial model and processes needed to do the modelling such as statistics, geo-statistical operations such Kriging, overlays and map algebra. A tool such as Modelbuilder from ESRI can be used in the engineering phase of the production.
- *Manage rules, performance, data, in-process products (WIP), equipment and facilities, transportation, production network and regulatory compliance for production.* Rules management ensures that the GIS unit complies with the unit's goals and strategies when a GIS product is created. Performance guides the GIS unit to create quality GIS products and one of the performance measures is how well the operator can perform certain GIS tasks. If a person does not perform adequately, that person needs to undergo training to enable him or her to perform the task satisfactorily. In-process products in the GIS context could involve one GIS person doing part of the work and then placing the work in the data warehouse where the next GIS person completes the task. An example is where a statistician does high-level statistical work on the data outside the

GIS and then makes the results available which are then further manipulated by a GIS person to deliver a spatial product. MAKE equipment and facilities are the software, hardware and other materials needed to create a GIS product. Facilities are the building or offices in which the GIS unit is housed. Transportation in the GIS context is the ability to move spatial and other data between users and the data warehouse via a LAN, WAN or the Internet. The production network is closely link with the in-process products. The GIS knows who is responsible for which parts of a GIS product and when these parts are available in the data warehouse. Regulatory compliance with production guides the GIS unit to adhere to ISO standards (ISO 900x and ISO 191xx). ISO 191xx standards are standards for the GIS community. The creation of metadata is compulsory and the minimum requirements as per ISO 19115 must be adhered to.

DELIVER looks at the orders received from customers as well as the warehousing, transportation and, if appropriate, installation management of the finished product. The finished product can be either a stocked product, make-to-order product or an engineer-to-order product (Supply-Chain Council, 2005). The following processes are addressed in DELIVER (Supply-Chain Council, 2005:4):

- *All order management steps from processing customer enquiries and quotes to routing shipments and selecting carriers.* When the GIS unit receives an enquiry for a specific GIS –product, and the GIS unit gives the customer a quotation against which the customer places an order for the GIS product. After validation of the order, the GIS unit then queries the data warehouse to establish whether such a GIS product is available (stocked product). If not, the GIS unit creates the GIS product, which is either a make-to-order product, as in the SAC example, or an engineer-to-order GIS product. Once the GIS product is available, the GIS unit consolidates the order and ships it to the client using an appropriate transportation mode such as the Internet or a courier service (3PL) to deliver a CD-Rom or DVD to the client.

- *Warehouse management from receiving and picking the product to loading and shipping the product.* Warehouse management in the GIS context is the management of the data warehouse by an assigned person from the GIS unit. The loading and shipping of the product is discussed above.
- *Receive and verify product at customer site and install, if necessary.* The client receives the GIS product and if necessary the GIS unit can verify the product at the customer's site, such as the correct file format or that the customer can work with data to create his own GIS product as part of the data supply chain partnership. Eskom's regional GIS users sometimes lack the necessary skills to use the GIS product delivered by ESI-GIS (De la Rey, 2005).
- *Invoice customer.*
- *Manage DELIVER business rules, performance, information, finished product inventories, capital assets, transportation, product life cycle and import/export requirements.* DELIVER business rules are those rules that the GIS unit applies with respect to customer and order verification, previous experience with the customer and the selection of 3PLs with respect to shipping CD-ROMs, DVDs or hard copies. Some firms have a dedicated courier company. Performance of the GIS unit includes perfect order fulfilment, where the GIS unit does not omit the metadata, or eliminates any other data problems that may occur. Information that a GIS unit needs to manage includes customer relationship management data, previous deliveries and data warehouse management (new GIS products are added to the data warehouse which must be captured in the inventory list). The data warehouse and other servers are part of capital assets. Transportation deals with the ability to move data over the Internet such as notifying the customer how to download the data from the GIS unit's FTP site or the list of 3PLs that can move the CD-ROMs, DVDs or hard copies for the GIS unit. Certain GIS products have a limited product life cycle owing to changes on the earth's surface. An example is land use/land cover maps. Urbanisation, the change of natural areas into agricultural production areas or the development of mines causes land use/land cover changes and necessitates the updating of existing land use/land cover

maps. A GIS unit may update its maps every year or every second year depending on policy. The GIS unit will then notify the customer of the updating schedule and delivery dates. Customers pay the GIS unit an annual maintenance fee for the GIS product, thus ensuring currency of the data. The GIS unit will deal with import/export requirements when required.

The **RETURN** process category deals with the return of defective products to suppliers as well as the receiving of defective, expired or excess products or products that are scheduled for maintenance that were delivered to the customers. When the products are returned to the supplier, the condition of the product must be established and the information passed to the supplier to request the return of the product. Once accepted by the supplier, the return shipment is scheduled and the product is returned. A similar process is followed when a defective product is returned by the customer. When a product has to be returned to the firm for maintenance, repair or overhaul (MRO), the receiving of the product follows the same steps as given above, including the return of the product to the customer. Similar steps are followed when the firm returns an MRO product to the supplier. With regard to excess products, the customer requests the return of the product after establishing its condition. Once authorisation has been given the return is scheduled and the firm receives the product. The firm follows similar steps when returning excess products to the supplier. Expired products follow the same process. Excess and expired products are then disposed of in appropriate manner. RETURN also manages the business rules regarding the return of products, the information on the number of returns or the customer list from which excess or expired goods must be received for proper disposal, the inventory of returned goods or goods that are to be returned to the supplier, the transportation as well as the regulatory requirements and compliance (Supply-Chain Council, 2005). In the GIS context RETURN is mostly concerned with the return of defective GIS products.

ENABLE processes are those processes that enable each of the process categories to function. The management processes as discussed in each process category are the ENABLE processes.

2.5.2.2 The three levels where SCOR is used

- The SCOR model operates on three levels (see Figure 2.3). On the first-level SCOR the supply chain is configured using the five core management process types. It has 13 performance attributes for which data are collected for the firm and its competitors to establish the firm's supply chain performance compared with that of its competitors. The 13 performance measures can be grouped into five performance categories namely: *Reliability,* which describes the delivery performance of the firm, the fill rates with respect to order fulfilment from stock within 24 hours of order receipt (Bolstorff and Rosenbaum, 2003) and perfect order fulfilment. Perfect order fulfilment indicates the number of non-defective orders delivered to the client, normally expressed as a percentage of all orders delivered. *Responsiveness* looks at how quickly the supply chain reacts to orders from the customers. It is measured in *order-fulfilment lead-times*, i.e. the number of days to deliver the order starting from when an order is received. *Flexibility* is concerned with whether the supply chain is flexible enough to handle changes such as an order surge for a specific product and how flexible the production is when a change occurs in a product according to customer needs. Both changes must be handled without incurring penalty costs (Bolstorff and Rosenbaum, 2003).

Cost is concerned with the following four cost types:

- Supply chain management costs (the direct and indirect costs of the whole supply chain).
- Cost of goods sold (material and labour cost to manufacture the product).
- Sales, General and Administrative costs.
- Warranty or return processing cost - the cost involved when defective products are returned for repair or replacement, planned maintenance of products as well as the cost of handling returned excess stock. It includes all the reverse logistics costs (Bolstorff and Rosenbaum, 2003).

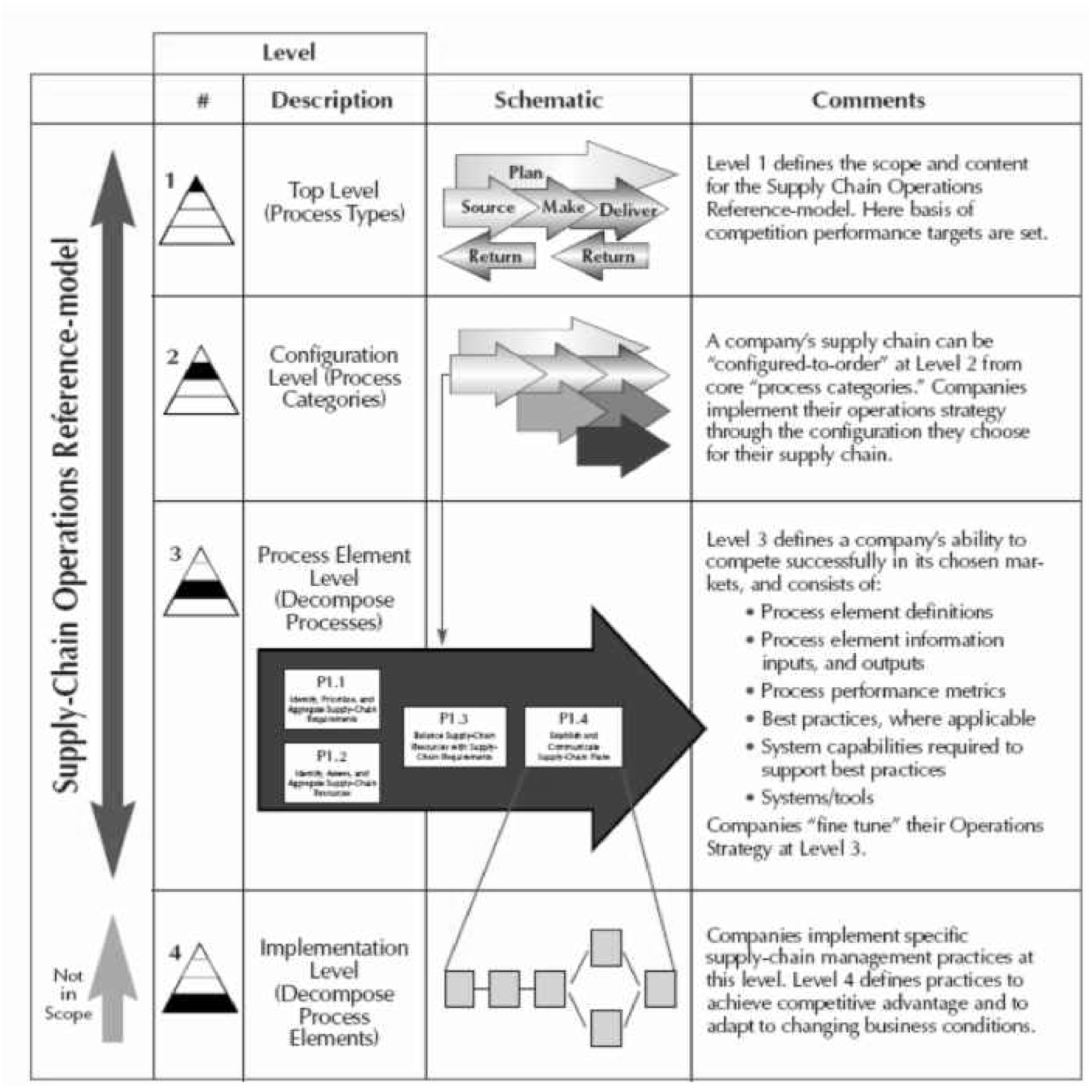

Figure 2.3: The three levels of the SCOR model

(from Supply-Chain Council, 2005:6)

The last performance category is *assets*, which deals with cash-to-cash cycle time, i.e. the number of days cash is tied up as working capital, and inventory days of supply looks at the number of days that cash is tied up as inventory and *asset turns* (Bolstorff and Rosenbaum, 2003 and Wisner *et al.*, 2005). *Asset turns*, according to Bolstorff and Rosenbaum (2003:52), *"is calculated by dividing revenue by total assets including working capital and fixed assets"*. The performance metrics are not necessarily linked to a specific process management category at Level 1 but could be cross-functional (Supply-Chain Council, 2005).

At Level 2 each Level 1 process category is unpacked into process categories. This is used to configure the supply chain to implement their operational strategies. At this level the different products, namely stocked, make-to-order or engineered-to-order products, drive certain processes (Supply-Chain Council, 2005). Figure 2.4 gives the Level 2 process categories in relation to the five process types of SCOR.

The planning (PLAN) part of the SCOR model at Level 2 is a process which aligns the resources to meet the expected demand from customers. The execution part of the supply chain is given in SOURCE, MAKE and DELIVER, with RETURN, where appropriate, and it is solely concerned with the manufacturing of the final product. The ENABLE part is the management process on which the planning and the execution of the supply chain relies (Supply-Chain Council, 2005).

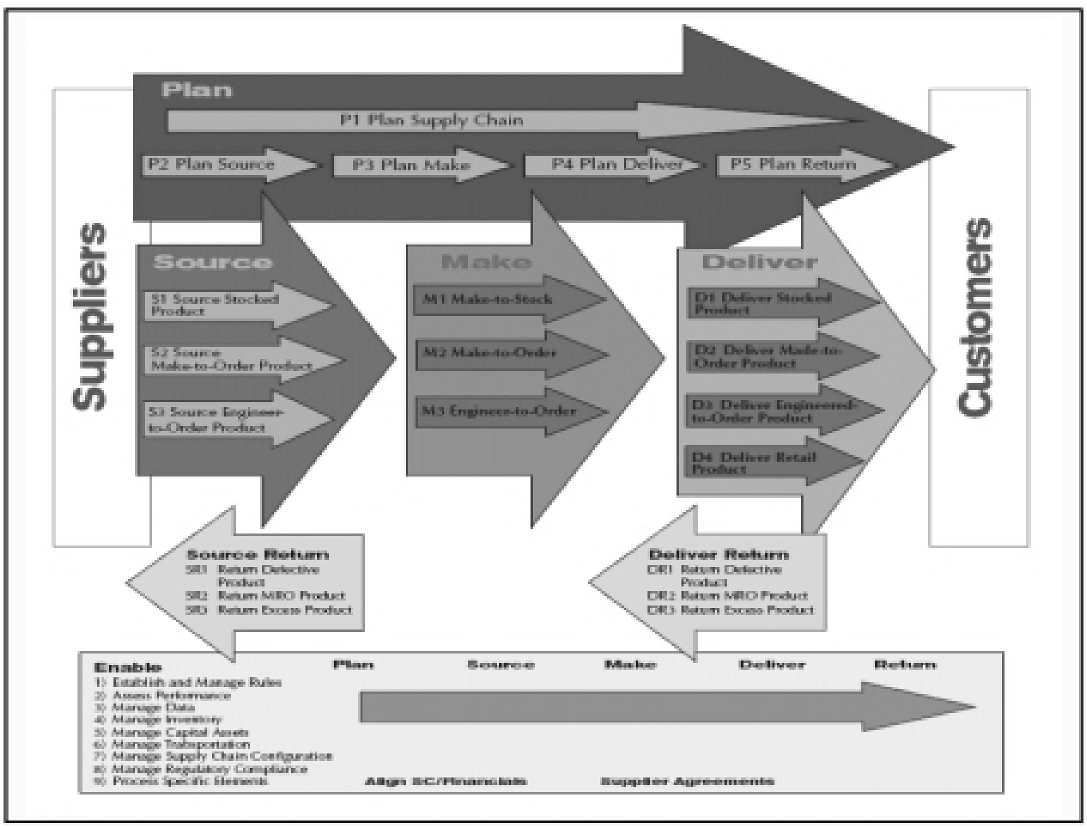

Figure 2.4: Overview of SCOR Level 2 process categories
(from Supply-Chain Council, 2005:9)

Level 3 decomposes each process category from Level 2 into detailed process elements. It looks at the process flow of activities, inputs to and outputs from each activity as well as the sources of the inputs and the destinations of the outputs (Supply-Chain Council, 2005). Figure 2.5 gives an illustration of a Level 3 breakdown of a Level 2 process category. Each process element has its definition, performance attributes and associated metrics, and a description of best practices and related features in industry (Supply-Chain Council, 2005). Table 2.1 gives an example of such a process element.

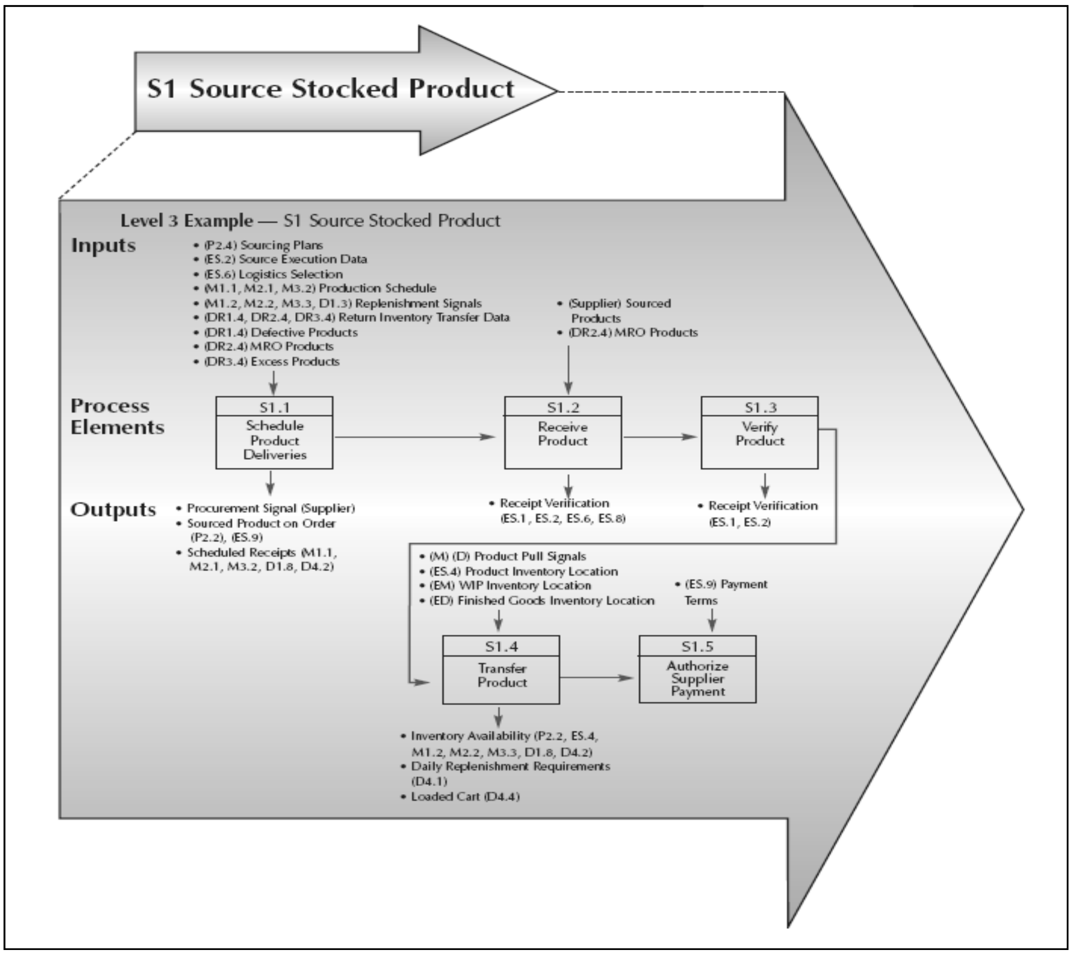

Figure 2.5: Level 3 process element logic flow

(from Supply-Chain Council, 2005:10)

The supply chain is configured at Level 2 to model the supply chain; every applicable process category is mapped and connected with each another in a logical flow format. In the SCOR model the process is started by drawing on a map the location of factories, distribution centres, warehouses and suppliers. Figure 2.6 gives an example of such a map for a GIS unit, ESI-GIS, at Eskom Distribution's head office where data are sourced from regional offices as well as other suppliers and delivers GIS products back to the regional offices for planning purposes. The various process categories mapped in Figure 2.6 such as M1, M2, D3 and S2 are explained in Figure 2.4.

Table 2.1: Process element definition, performance and best practices

Process Element: Schedule Product Deliveries **S1.1** (see Figure 2.5)	
Process Element Definition Scheduling and managing the execution of the individual deliveries of product against an existing contract or purchase order. The requirements for product releases are based on the detailed sourcing plan or other types of product pull signals.	
Performance Attributes	**Metric**
Reliability (see above for descriptions)	% Schedules generated within supplier's lead time % Schedules changed within supplier's lead time
Responsiveness	Schedule product delivery cycle times (from placing of order to reception of product)
Flexibility	None identified
Cost	Schedule deliveries costs as a % of product acquisition costs
Assets	Return on supply chain assets
Best practices	**Features**
Utilise EDI transactions to reduce cycle time and costs	EDI interface for 830, 850, 856 and 862 transactions
Mechanical (Kanban) pull signals are used to notify suppliers of the need to deliver product	Electronic Kanban support
Consignment agreements are used to reduce assets and cycle time while increasing the availability of critical items	Consignment inventory management
Advanced shipping notices allow for tight synchronisation between SOURCE and MAKE processes	Blanket order support with scheduling interfaces to external supplier systems
Vendor Managed Inventory	See Glossary

(Supply-Chain Council, 2003:11)

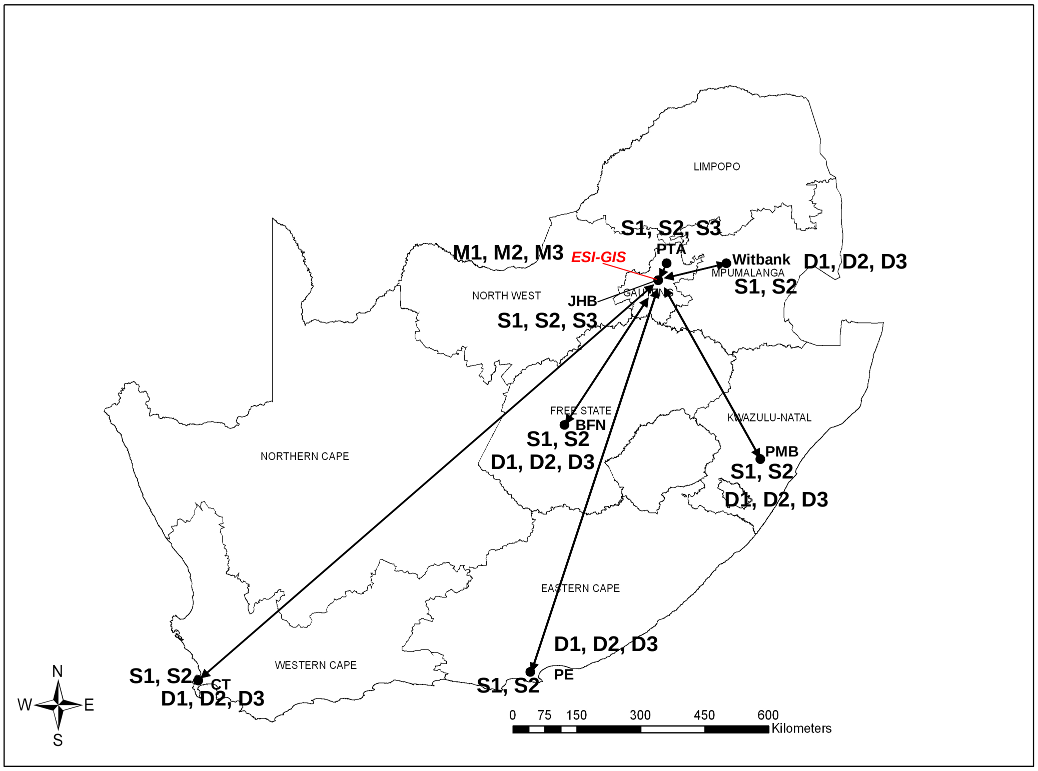

Figure 2.6: Supply chain flow between the GIS unit and regional offices
(from De la Rey, 2005)

In this example the regional offices are both suppliers and customers of spatial data. The regional offices use the data for planning purposes, add new data based on the execution of the plans and return them to ESI-GIS which uses the data for the creation of the next set of GIS products. Other suppliers that are not mapped are the SAC, Surveys and Mapping and other GIS firms such as GIMS (De la Rey, 2005). This is then translated into a SCOR process map showing the Level 2 process categories as well as each supply chain thread, using different line symbols to differentiate between planning and execution threads. Figure 2.7 shows the SCOR process map based on Figure 2.6. The various process categories in Figure 2.7 are explained in Figure 2.4.

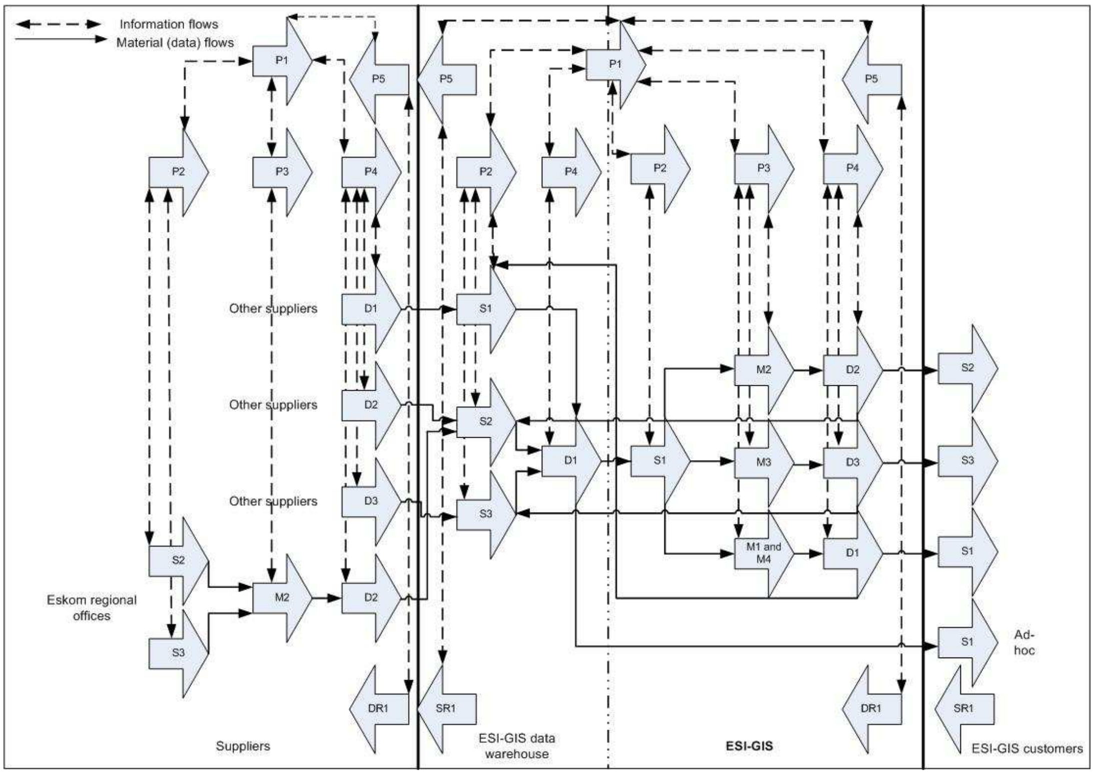

Figure 2.7: ESI-GIS SCOR Level 2 process map

Once the SCOR Level 2 process map has been finalised these identified process categories can be decomposed into detailed process elements as shown in Figure 2.5. This section examined SCOR, what it is, its range and the three levels on which the supply chain modelling is executed. SCOR is used to map the AS IS situation and then used to develop and model the TO BE supply chain based on the results of the measurements and evaluations of the configured supply chain (Bolstorff and Rosenbaum, 2003 and Supply-Chain Council, 2005).

2.6 Conclusion

The research question given in Section 1.5 necessitated a more detailed discussion of supply chains and supply chain management to allow them to be applied in the GIS environment. From the above discussions it is apparent that supply chains clearly define the movement of products from the supplier to the firm and from the firm to the customer using various processes such as procurement, inventory management, transportation, warehousing and operations. This flow of products and various processes in the supply chain are managed to ensure that the customer receives the right product, at the right time, in the right condition and quantity. This management is known as supply chain management.

In Section 1.1 a clear need for GIS units to be able to access and/or disseminate the right data at the right time and in the right format was identified. This need is similar to the one discussed in the previous paragraph and clearly indicates that supply chains and supply chain management can be used by a GIS unit to address its identified need. Section 1.1 further indicated that there are currently two management approaches available to GIS, namely a holistic and project-level approach using workflows. From the discussions in this chapter it is clear that supply chain management is also a holistic approach as demonstrated by the SCOR model. This holistic approach is different to the holistic management currently used in GIS as referred to in Section 1.1, since it looks at the whole supply chain from the supplier to the firm and from the firm to the customer with flows of products, information and money up and down this supply chain. It further includes the creation of relationships and quality control with the aim of being as efficient and cost effective as possible in order to out-perform the competition.

Based on the above discussions, it can be concluded that supply chains and supply chain management will be able to address the needs of a GIS unit in terms of accessing and/or disseminating data and the management thereof. There is the possibility that some of the aspects of supply chains and supply chain management discussed in this chapter, i.e. warehouses and inventory management approaches, may not be applicable to GIS units and GIS as such. It is thus necessary to establish which of the above discussed aspects are not applicable. This can only be done by discussing GIS in detail to determine a) whether GIS lends itself to the establishment of supply chains and b) how GIS units are currently managed in order to respond to the abovementioned need and to answer the research question. Chapter 3 will discuss GIS in more detail in order to determine a).

Chapter 3: Geographic Information Systems (GIS)

3.1 Introduction

In order to achieve objective B, “**What is GIS and where it is applied?”** it is necessary to understand what GIS is, how GIS developed over the decades, the principles of GIS and the applications of GIS. This discussion of GIS is necessary since this is what the GIS unit uses as a tool to create a GIS product as well as to establish whether GIS lends itself to the use of supply chains and the application of supply chain management.

The definitions of GIS as discussed in Chapter 1 will be expanded to illustrate that the definition of a GIS implicitly indicates a supply chain. Once the definition for the purpose of this research has been established, the principles of the GIS are discussed. These range from the nature of spatial data, which looks at how the real world will be modelled in the GIS namely using points, lines and polygons or a regular set of cells in a grid (the raster model), to operational issues such as implementing a GIS, the legal aspects with regard to GIS and GIS standards.

To illustrate the wide range of GIS applications, several examples are given, which show the need for managing GIS to ensure that GIS products are produced efficiently and effectively in the shortest possible time. In these examples it will be demonstrated how the nature of GIS lends itself to be considered as supply chains using the SCOR model in order to answer part of the research question.

3.2 History

The history of GIS began as mentioned in Section 1.1 when it was developed in the 1950s to assist in the analysis of agricultural data. GIS underwent several developmental stages up to Web-enabled GIS which distributes data and results over the Internet.

Coppock and Rhind (1991) identified four stages in the development of GIS from the 1950s up to 1991. The four stages are:

- First stage or pioneering age (1960 – 1975).
- Second stage: *Research and Development Age* (Foresman, 1998) (1973 – early 1980s)
- Third stage or stage of commercial dominance (1982 to late 1980s), also called *Implementation and Vendor Age* (Foresman, 1998).
- Fourth stage or stage of user dominance (late 1980s onwards), or *Client Application Age* (Foresman, 1998).

A fifth stage or Internet/intranet stage would be appropriate since this is the direction in which GIS applications are moving. ESRI's ArcGIS System (ESRI, 2002) approach is such an example. Foresman (1998) calls this the *Local and Global Network Age*. Each of the different stages is discussed in more detail below.

3.2.1 First stage or pioneering age (1960 – 1975)

Although the first official GIS, namely the Canada Geographic Information System (CGIS), was developed in the 1960s (Longley *et al.*, 1999) in response to the Canadian government's need for a land inventory system (Foresman, 1998), earlier attempts had been made to use computers for geographical analysis. According to Longley *et al.* (1999), the earlier computers were "number crunchers" and were not able to deal with spatial data. During the 1950s in the United Kingdom, agricultural data were analysed and the computer was used to produce the results in such a form that they could be manually transferred to a map (Longley *et al.*, 1999:2).

In the 1960s main frame computers were becoming more readily available in the United States, and that stimulated the development of computer-assisted small-area data analyses, computer mapping as well as address matching (ADMATCH) (Coppock and Rhind, 1991).

A notable event during this phase was the development of topology by the US Census Bureau. Topology is spatial attribute data which describe the spatial entities and relationships between them. In the case of the US Census Bureau it was as follows for each line segment (Cooke, 1998):

- Street Name.
- From Node.
- To Node (gives the direction).
- Left Tract/block.
- Right Tract/block (left and right are determined by looking from the From Node to the To Node).
- Left Address Range (e.g. 1 to 99).
- Right Address Range (e.g. 2 to 100).
- ZIP Left (similar to our postal codes).
- ZIP Right.

In 1964 the Harvard Laboratory for Computer Graphics developed SYMAP which used a line printer as a mapping device. It could produce isoline, saturated analysis, choropleth and proximal maps (Coppock and Rhind, 1991:28, Foresman, 1998) and became the first widely used computer package that could handle geographic data (Foresman, 1998). Several other systems (only a few are given below) that developed during this pioneering phase are (Coppock and Rhind, 1991):

- ODYSSEY (Prototype of a vector GIS).
- GRID (a cell system that could overlay data).
- CALFORM (successor to SYMAP which used a pen plotter as a mapping device).
- Geographical Information Retrieval and Analysis System (GIRAS) in 1973.
- Minnesota Land Management Information System (MLMIS).

3.2.2 Second stage (1973 – early 1980s)

The second stage according to Foresman (1998) was the research and development age. During this phase, further developments were made in the GIS field which built on the ground-breaking work done during the first phase. These were mostly done within, and fostered by, different national agencies (Coppock and Rhind, 1991). During this period GRID was developed into IMRID (Information Manipulation on a Grid), which used English key words to initiate spatial operations such as OVERLAY, SEARCH and RECODE (Jordan and Rado, 1998).

Other examples during this period were the development of Dual Independent Map Encoding (DIME) using topological principles to describe urban structures (Coppock and Rhind, 1991 and Cooke, 1998). ARITHMICON developed from DIME, as an online file editor for DIME (Cooke, 1998). DIME then developed into TIGER (Topologically Integrated Geographic Encoding and Referencing), which was used for the 1990 census in the USA and is still in use (Coppock and Rhind, 1991 and Cooke, 1998). Another example from this period is the involvement of the United States Geological Survey (USGS), which led to the development of GIRAS (Geographical Information Retrieval and Analysis System), which could handle large spatial data sets (Coppock and Rhind, 1991). The last example in this section is the development of state systems such as the Minnesota Land Management Information System, which looked at land parcels, land ownership and environmental data (Coppock and Rhind, 1991). The Multi Purpose Land Information System (MPLIS) was developed as part of a bigger project by the University of Wisconsin – Madison, and was used in several counties in Wisconsin (Moyer and Niemann, 1998).

During this phase, Automated Mapping and Facilities Management (AM/FM) reached its peak of development and applications. Due to the rapid development of GIS (as a separate entity), the boundaries between AM/FM and GIS became blurred and there are several references to AM/FM/GIS in the literature (McDaniel *et al.,* 1998).

3.2.3 Third stage or stage of commercial dominance (1982 to late 1980s)

Due to the “spreading of the word” through user groups, newsletters and conferences such as those organised by the Urban and Regional Information Systems Association (URISA), several GIS software developers established themselves during this period. Notable are ESRI (Environmental Systems Research Institute) and Intergraph (Coppock and Rhind, 1991). There were others as well and some that did not make it. An example of the latter is ODESSY, a vector GIS (Faust, 1998), from the Harvard Laboratory, which faltered due to a bad deal with a computer graphic firm (Coppock and Rhind, 1991).

ESRI started as a consultancy using GRID. It developed the Polygon Information Overlay System (PIOS) which then resulted into ArcInfo in the early 1980s (Coppock and Rhind, 1991; Faust, 1998 and Greenlee and Guptill, 1998). ArcInfo, because its operability over a wide range of computer systems from a huge main frame computer to the personal computer (PC), made ESRI a market leader in GIS, and is still today in that position. By the end of the 1980s, ESRI sold about 2000 GIS systems a year and grew from a staff complement of 15 (in the early 1970s) to over 350 (in the early 1990s) (Coppock and Rhind, 1991). ESRI uses user conferences all over the world to provide continuous support for its products, as well as in-house publications (ESRI Press), such as *GIS for Everyone* by Davis (1999), *Confronting Catastrophe: A GIS Handbook* by Greene (2002) and *Connecting Our World: GIS Web Services* by Tang and Selwood (2003).

In 1978, the Earth Resources Data Analysis Systems (ERDAS) Inc. developed ERDAS to run on a microcomputer, i.e. a low-cost personal workstation. ERDAS developed from IMGRID and has the ability to process Landsat data. The ERDAS 400 system had turnkey solutions and the whole system was made available to customers in 1979, thus paving the way for commercialisation. ERDAS was the first image processing and raster GIS tool. In the early 1980s, ERDAS moved its software to IBM PC/XT and AT systems (ERDAS-PC). The biggest coup for ERDAS was the link-up with ArcInfo from ESRI (Jordan and Rado, 1998).

During this phase, several GIS systems were made commercially available and several firms, institutions and public sector organisations implemented GIS as a tool to provide services. Some of these were successful and some were not so successful. GIS also became entrenched in academia, which led to the establishment of the National Centre for Geographic Information and Analysis in the late 1980s (Foresman, 1998).

3.2.4 Fourth stage or stage of user dominance (late 1980s onwards)

The users of GIS are dominating this phase and the vendors are reacting to the clients' needs. This phase is marked by user conferences worldwide. An example is the ESRI user conferences, such as the 1995 ESRI User Conference that attracted more than 5 000 delegates (Goodchild, 1998). These conferences are used to disseminate information on the application of GIS in various fields such as utilities, town planning, transport and law enforcement to name but a few.

During this phase, GIS data products are being developed that can be purchased by users. An example is AmpsPlus released by the Knowledge Factory in South Africa, which uses the All Media and Product Survey (AMPS) data published by the South African Advertising Research Foundation (SAARF), as well as data from its ClusterPlus (which breaks down the 8 000 suburbs in South Africa into 10 homogenous and 38 detailed clusters, based on geodemographic data) and CensusPlus. The Knowledge Factory then extrapolates the AMPS data to suburb level and makes it available to its clients as AmpsPlus (Biz-Community, 2003). This data are used by marketers to identify possible or potential markets for their products using a GIS.

GIS developers and vendors provide specialist GIS solutions to their clients based on their needs. ESRI developed several custom GIS packages, either in-house or with a third party to fulfil a specific need. A few examples are given below of specialist GIS programs developed by ESRI. These are normally add-ons to a base GIS product such as ArcInfo or ArcView (part of the ArcGIS suite) (ESRI, 2000):

- ArcLogistics Route for vehicle routing and scheduling.
- ArcView Business Analyst for customer market analysis, customer prospecting, etc. using business data from data vendors.
- Maplex for cartographic production.
- *RouteMap* IMS, which is an Internet-based site locator application that can generate driving directions.

Apart from developing software, ESRI also provides professional services ranging from help with the implementation of GIS, to training of users to developing turnkey applications (ESRI, 2000). This is based on one of ESRI's success factors, namely "Listen to Our Users" (ESRI, 2000). There are a multitude of GIS developers and vendors who run their products on similar principles such as MapInfo and Intergraph.

3.2.5 Fifth stage: Local and global network age

With the establishment of the Internet as a general-purpose tool to access information on any topic anywhere in the world, as well as the development of intranets, mostly in big corporations, it is most logical that geographic information will be and is currently being distributed over the Internet and intranets. These distributions are either in the form of spatial data in map form (static or interactive), or allow the user to remotely access GIS functionality, ranging from simple spatial activities such as distance calculations to complex spatial modelling and analysis (Tang and Selwood, 2003). This is known as distributed geographic information (DGI) applications (Plewe, 1997) or GIS Web services (Tang and Selwood, 2003).

An example is the Geography Network, developed by ESRI, which provides a Web-based catalogue of Internet services, spatial data, maps or GIS functionalities. Figure 1.1 in Chapter 1 illustrates the Geography Network concept (Tang and Selwood, 2003). Other examples of the Geography Network are GIS portals that allows sharing of geographic information over the Internet using Web-based catalogues, but which are software independent with regard to GIS. However, the Geography Network is dependent on ESRI software products. GIS portals promote interoperability between different GISs, and the Open Geospatial Consortium with ISO is developing interoperability standards.

According to Hogeweg (2005) a GIS portal consists of the following components (see Figure 3.1):

- A metadata catalogue centrally located with regard to the GIS portal which consists of metadata documents of all the data that are available through the portal.
- Remote services described in the metadata catalogue, which gives indications to users on what is available and where and how to access maps and/or geoprocessing capabilities.
- A user interface that consists of a set of applications through which the users interact with the GIS portal.
- Remote catalogues that are the same as the metadata catalogue, as discussed above, which reside at remote sites such as another GIS portal or at specific organisations that are part of the GIS portal, but also serve other areas.
- Harvesting allows for the users of the GIS portal to update the metadata catalogue with new geographic information that becomes available.

Another example of the use of geographic information on the Internet is Maporama (www.maporama.com), which allows the user to view locations (in interactive map form) in most countries in the world. The Knowledge Factory provides the South African data to Maporama. A South African example of a GIS Web service is SA-ISIS, which was developed by the CSIR, ARC and other consortium members and acts as a clearing house to access geographic data from various sources (Tucker, 2003).

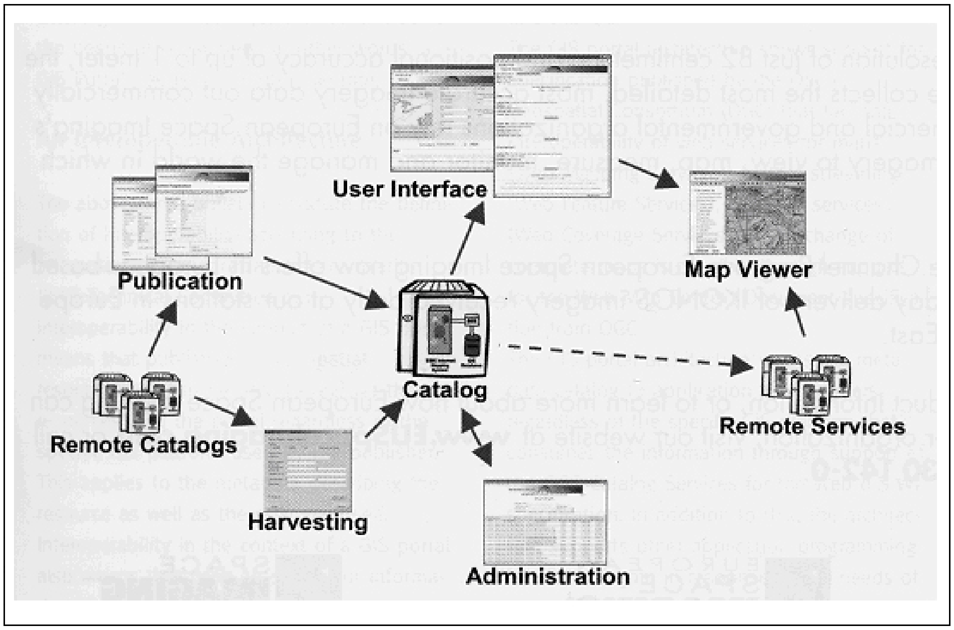

Figure 3.1: Components of a GIS portal
(from Hogeweg, 2005:21, Figure 2)

3.3 Definition of GIS

In Chapter 1 a few definitions of Geographic Information Systems (GIS) were given to illustrate that the definitions of a GIS indicate elements of a supply chain such as sourcing, manipulation and displaying data. As with supply chains and supply chain management (see Chapter 2, Section 2.3), there are several definitions of a GIS. Some definitions by various authors are given below from which a definition for the purpose of this study will be extracted:

Dueker (1979:106) as quoted in Maguire, 1991:

> *"A special case of information systems where the database consists of observations of spatially distributed features, activities or events, which are definable in space as points, lines, or areas. A GIS manipulates data about these points, lines and areas to retrieve data for ad hoc queries and analyses."*

Koshkarov, Tikunov and Trofimov (1989:259) as quoted in Maguire, 1991:

> *"A system with advanced geo-modelling capabilities."*

These two definitions emphasise the manipulative capabilities of a GIS. The following three definitions define the main capabilities of a GIS, which range from acquiring to displaying data:

Ozemoy *et al*. (1981:92) as quoted in Maguire, 1991:

> *"An automated set of functions that provides professionals with advanced capabilities for the storage, retrieval, manipulation and display of geographically located data."*

Burrough (1986:6) as quoted in Maguire, 1991:

> *"A powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world."*

Eastman (2001:5):

> *"A Geographic Information System is a computer-assisted system for the acquisition, storage, analysis and display of geographic data*."

The following definition combines all the above definitions in more general terms:

Goodchild (1998:370):

> *"At its most broad, GIS now refers to any activity involving geographic information in digital form."*

Maguire (1991) indicates that there was, or it still is, a debate about whether the definition of a GIS should be a narrow technical one, as given above, or whether it should be broader to include the organisational or institutional perspective. A broad definition of GIS is given by Carter (1989) as referenced in Maguire (1991) as follows:

> *"(A GIS is) an institutional entity, reflecting an organisational structure that integrates technology with a database, expertise and continuing financial support over time."*

This broad definition gives a hint as to management (expertise) but does not give it explicitly. For the purposes of this study, the narrow definitions of GIS as given above especially in Ozemoy *et al.*, Smith and Sicherman's, and Burrough's and Eastman's definitions, which are the focus of any GIS used by a single person or by organisations or institutions, are expanded to include the management of GIS. Dickinson and Calkins (1988) as referenced in Maguire (1991:11) argue that a GIS comprises the following three key components:

- GIS technology, which consists of hardware and software.
- GIS data base(s) that contain(s) the geographical and related non-geographical data.
- GIS infrastructure, which consists of staff, facilities and supporting elements.

For this research, the definition of a GIS is expanded to include the three key components of GIS as presented by Ozemoy *et al.* (1981) as quoted in Maguire, 1991, as well as Burrough's and Eastman's definitions of GIS. Based on the above, the definition can be given as follows:

> *A GIS is a **computer-assisted system**, combined with appropriate **infrastructures, resources and management**, that **acquires, stores, retrieves, transforms, manipulates** and **displays geographical and related non-geographical data**.*

This definition of a GIS can be used in any type of GIS application, whether for land information management, decision support, facilities management, or research and development. To be able to run any type of GIS application:

- The data have to be sourced form various suppliers (Burrough's collection and Eastman's acquisition).
- The sourced data need to be manipulated by the GIS to find answers for the application (Burrough's storing, retrieving at will, transforming and

displaying; Eastman's storage, analysis and display; and Ozemoy *et al.'s* storage, retrieval, manipulation and display), which is a GIS product.

- The GIS product is delivered to a client, where the client will display the product after its acquisition.
- Proper infrastructure and resources must be in place to enable the above processes.
- All the above must be managed to ensure an efficient and effective GIS application.

The sourcing, storing (which resembles inventory and/or warehousing) and manipulating of data (spatial and non-spatial) as well as delivering the GIS product, indicate a typical supply chain. This necessitates supply chain management to ensure the effective use of GIS, especially in a large organisational or institutional set-up, or if a large number of different data sets are utilised. An example of the latter is *e-Land* as discussed in Section 1.4. The definition as given above, for the purpose of this research, consists of several concepts such as data, storage, retrieval and manipulation. These concepts are discussed in more detail in the section on the principles of GIS below.

3.4 Principles of GIS

Section 3.3 dealt with a few definitions of GIS as well as the three components that a GIS comprised of, which led to the formulation of a new definition of GIS that includes infrastructure, resources and management. This definition of a GIS intrinsically describes a supply chain and thus requires supply chain management to manage the GIS during the creation of a GIS product. This section deals with the principles of GIS and attempts to give a better understanding of what a GIS is and to expand the definition as given in Section 3.3 for this research, as well as to lay the foundation for the successful management of GIS. An overview of the principles of GIS is given so as to expand on the concepts within the definition. An in-depth examination of the principles of GIS is outside the scope of this research.

The discussion of the principles of GIS can be grouped under the following five headings, namely: the nature of spatial data; the digital representation of spatial data; the functional issues of GIS; the display of spatial data in a GIS and the operational aspects of a GIS. This approach is broadly used by Maguire, Goodchild and Rhind (1991); Korte (2001); Longley *et al.* (2001) and Bernhardsen (2002).

3.4.1 The nature of spatial data

> *A GIS is a computer-assisted system, combined with appropriate infrastructures, resources and management, that acquires, stores, retrieves, transforms, manipulates and displays* ***geographical and related non-geographical data****.*

By its nature, spatial data is concerned with the geographical and related non-geographical data of the definition. Spatial data are the commodity, the GIS product, which has to be managed when spatial data are sourced, manipulated and delivered to a client (display). Spatial data looks at the concept of space in a GIS, i.e. space is expressed in a GIS as a relationship between spatial features. Spatial features are expressed as objects that have a spatial (geographical) component as well as locational attributes (non-geographical) that place and describe the feature at a specific location in space such as a road or a borehole or a farm (Bernhardsen, 2002). Spatial features such as boreholes, erven, farms, rivers, roads, and mountains are derived from the real world and are represented in a GIS as a point, a line or a polygon. Points describe objects such as boreholes and oil wells. Rivers and roads are examples of a line feature consisting of points that are interconnected with a start and end point and shows a direction. Polygons or areas (erven and farms) consist of lines where the first and the last points have the same location. Points in lines and polygons are known as nodes and are joined by vertices (Bernhardsen, 2002 and Bolstad, 2005).

The relationships between spatial features are, for example, those points that are neighbours within a specified distance of a selected point, the type of road that joins another road at a specific location, or which farm is adjacent to the farm referred to as *Cyferfontein* (Catrell, 1991). Topology is a special form of relationship that is used to enhance spatial operations using lines and polygons. An example of topology is a line that has a begin node and an end node which indicates direction`, and if the line is a segment of a polygon it may also have the left and right polygon information (Bolstad, 2005).

Since the above are models of objects that occur on the earth, they must be represented as accurately as possible in the GIS environment. Spatial features in GIS are visualised on a computer screen which is a flat surface, similar to the traditional map. The representation of the spatial features uses map projections to render the geographic coordinates which are based on a datum on the computer screen. The spatial features can be represented on the screen using either a raster or vector model.

A datum is based on an ellipsoid (a model) that defines the shape of the earth, which is flattened at the poles and bulges at the equator due to gravitational forces. Several ellipsoids have been developed to suit geodetic surveys based on local conditions. A datum is a local (countrywide) reference system in which the coordinates of a spatial feature can be determined using a set of accurately determined points or benchmarks with known coordinates. Examples of ellipsoids used for a local datum are Clarke 1880, Clarke 1886 and Bessel 1841. WGS84 is an ellipsoid used as a worldwide datum, which was determined from measurements using satellites, lasers and broadcast timing systems (Berhardsen, 2002 and Bolstad, 2005). A detailed discussion on ellipsoids, datum and geodesy is outside the scope of this research.

The coordinates, which are referenced to a datum (ellipsoid), and which are used to determine a location on the earth's surface are known as geographic coordinates and are expressed in degrees, minutes and seconds. Variations in a north-south direction are known as latitudes, and longitudes describe the variations in a east-west direction. These coordinates originate from the centre of the Earth as determined by the selected datum, based on a specific ellipsoid, and end at the surface of the ellipsoid. The equator is defined by convention as zero degrees latitude and any variations to the North Pole are designated latitude north and the variations to the South Pole are latitude south. The latitudinal range is 90 degrees north and 90 degrees south. The Greenwich Meridian was designated as the zero longitude, thus variations in longitude west of Greenwich are known as longitude west and the variations to the east are known as longitude east. The range is 180 degrees west and 180 degrees east (Bernhardsen, 2002 and Bolstad, 2005).

Once the coordinates of the spatial features have been selected for a specific GIS project, they must be represented on a computer screen or printed on paper by the GIS. This representation is done using map projections. A map projection is the systematic rendering of the coordinates that have been determined on a curved Earth onto a flat surface such as a map or a computer screen (Bolstad, 2005). Maling (1991), Bernhardsen (2002) and Bolstad (2005) discuss the different transformation methodologies employed to map a real-world location given in geographical coordinates onto a map where the location is expressed in degrees or metres. The Lambert Conformal Conic and Transverse Mercator are the most commonly used in GIS (Bolstad, 2005). Figure 3.2 and 3.3 gives an example of these projections.

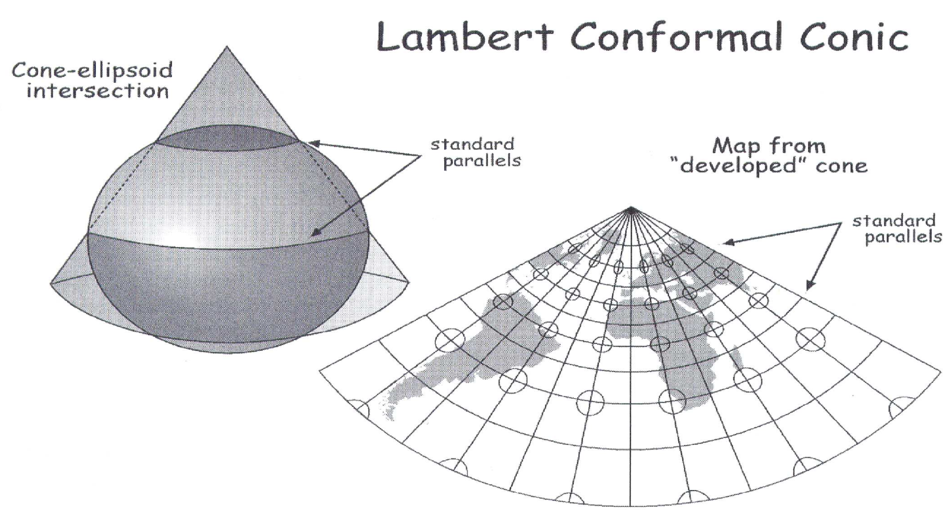

Figure 3.2: Lambert Conformal Conic map projections
(from Bolstad, 2005:93, Figure 3.26)

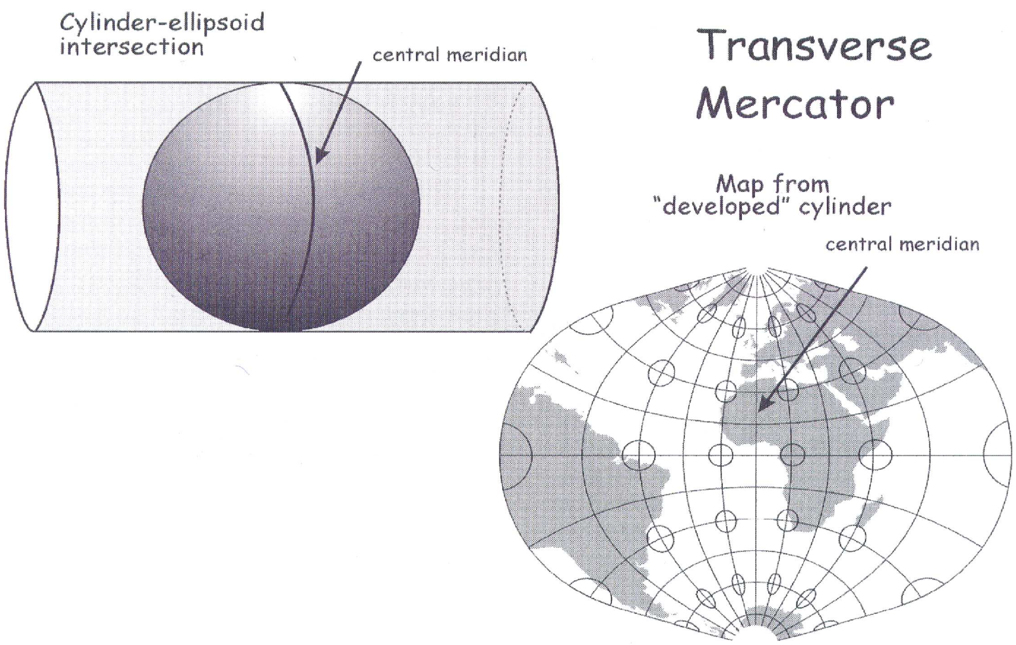

Figure 3.3: Transverse Mercator map projections
(from Bolstad, 2005:93, Figure 3.26)

GIS uses two different models to represent the projected coordinates of a selected spatial feature. The first model is a vector model that uses points, lines and polygons using projected coordinates to map the real world (Bolstad, 2005). Figure 3.4 gives an example of the different vectors.

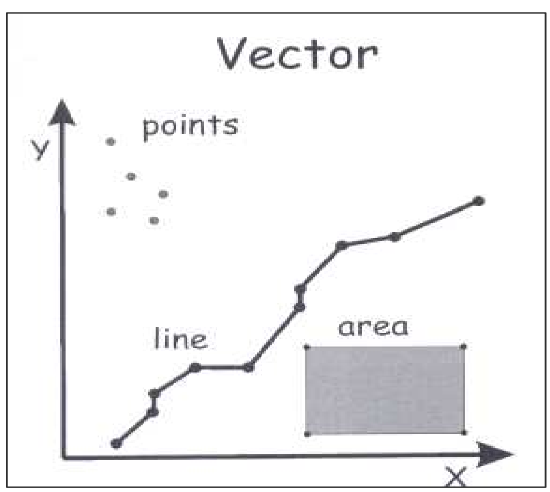

Figure 3.4: Vector data model
(from Bolstad 2005:31, Figure 2.8)

Vector data according to Bolstad (2005) makes use of a set of coordinates and related attribute data to define a discrete object in geographic space. There are two types of vector models, namely the spaghetti vector model which shows no relationships between different entities, and the topological vector data model which shows relationships between entities such as adjacency and connectivity. Topology does not change when spatial entities are changed due to geometric transformation such as stretching or bending (warping) (Bolstad, 2005).

Attribute data are linked to the vectors describing the features. The points in Figure 3.4 can represent boreholes (depth of the well and the yield in litres per hour), the line can represent a river (chemical composition, depth and navigation capabilities) and the polygon can represent a land parcel (size, use, owner and when proclaimed). Vectors such as hexagons, bricks and squares, which are special polygons, can be used to describe a continuous surface such as rainfall or population distribution. Flowmap, a specialist form of GIS, uses the above to determine accessibility to facilities as well as the expansion and reduction (closure) of facilities using various algorithms (De Jong, 2006).

The second data model that a GIS uses to map selected spatial features is the raster model. In the raster model the world is represented in the form of a regular set of cells in a grid evenly spread in an x and y direction. Generally these cells are squares and each cell has an attribute describing the spatial feature it represents (Bolstad, 2005). The above vectors as given in Figure 3.4 are represented in the raster model in Figure 3.5.

Points, lines and polygons describe discrete individual spatial features, whereas surfaces such as rainfall or elevation are represented by regular tessellation, either using raster grids or vectors such as hexagons or squares, and irregular tessellation, e.g. a triangular irregular network (TIN), of a surface is used to model change over space.

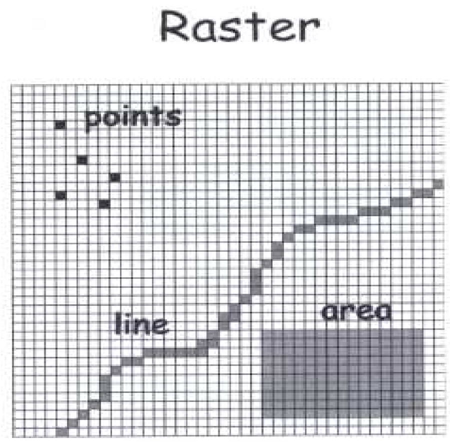

Figure 3.5: Raster data model

(from Bolstad 2005:31, Figure 2.8)

Lines connecting locations of equal value such as contours or isohyets are also used to show changes in surfaces (Bolstad, 2005). The elevation data in Figure 3.6 are displayed either as a raster, contours or TIN (Bolstad, 2005).

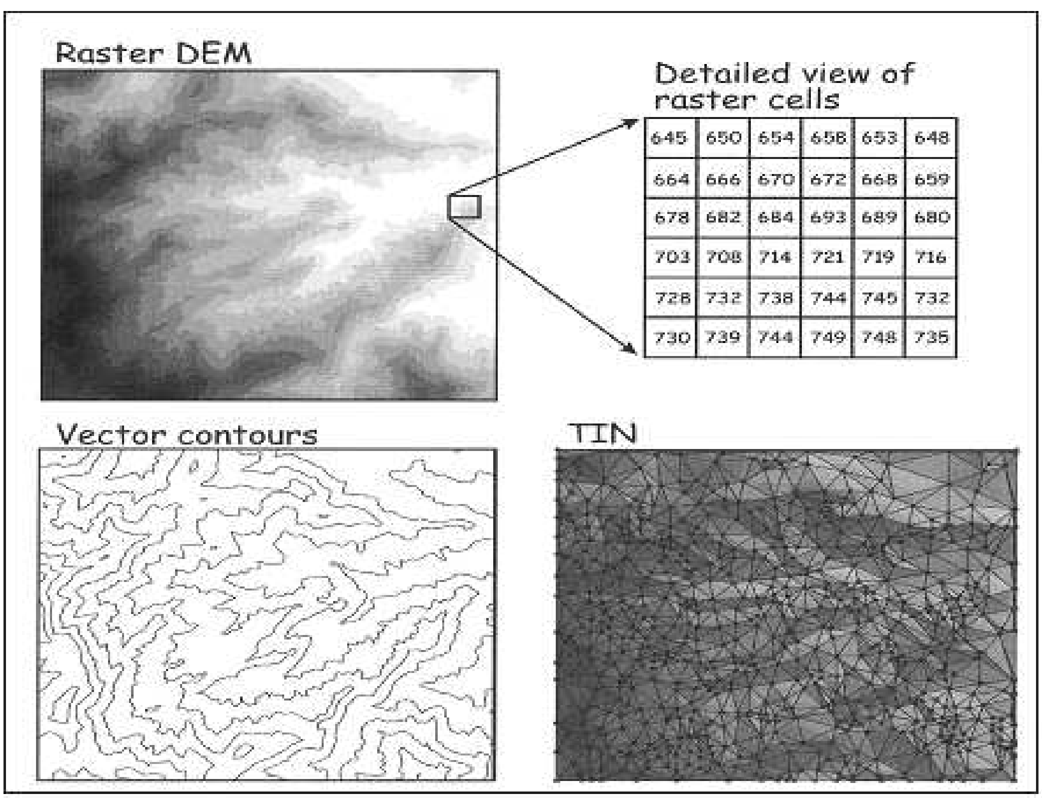

Figure 3.9: Different models to describe a surface in GIS

(from Bolstad, 2005:51, Figure 2.26)

Spatial data and their related non-spatial data as discussed above are prone to data errors. Burrough (1986 as quoted in Bernhardsen, 2002) indicates three sources of spatial and related non-spatial data errors. The first source of data errors are errors that occur in the original data before it is processed by a GIS, such as surveys carried out where instrument inaccuracies such as surveying and attribute collection instruments, GPS and satellite sensor systems cause errors. Other errors in this category are errors in paper maps, the currency of the collected data and the lack of resolution or coverage. The second source of errors are those errors introduced by the GIS when processing data, such as wrong data entered into a GIS through inaccurate digitising of features or wrong attribute data capture and errors caused during data manipulation such as raster-to-vector or vector-to-raster conversion and interpolation. The third group of errors are caused by the method of data collection employed, such as insufficient number of observations to give an accurate measurement of the object(s) observed, errors in identifying features, and the lack of experience of the data collectors.

Examples of the abovementioned errors are discussed in the next few sections. Positional inaccuracies are those caused by using data that have been captured at a scale of 1:50 000 but used in analysis of the data at a scale of 1:5 000. If attribute data are incorrectly captured, either through faulty instruments or the lack of experience of the data capturers, it can lead to attribute data inaccuracy, such as the misclassification of land use owing to the lack of experience in satellite imagery interpretation. Another example of errors are those errors caused by questionable currency of the data or when the observations are incorrectly time stamped, which leads to temporal inaccuracies. Logical inconsistencies such as topological inconsistencies are caused during GIS data manipulation or when digitising a map.

Examples of topological inconsistencies are overshoots (lines that cross other lines, whereas they should connect at lines such as the t-junctions of roads) and undershoots (where a line should connect to another line but does not), double lines, sliver polygons that occur during the digitising of neighbouring polygons or during overlay operations, and polygons that are not closed. Data capturers cause domain inconsistencies when they capture values that are outside the given domain, such as unrealistic temperature readings or measurements made outside the acceptable measurement error.

Completeness is affected by the lack of data or an excess of data captured, which is measured against a specification set with regard to the data that must be collected. Completeness is described in terms of too much data present or the lack of data in a dataset (Bernhardsen, 2002). Errors can be minimised through quality control and the proper creation of metadata (data about the data) that include information on position, attribute data and temporal accuracy, as well as logical consistency and completeness of the data. Metadata alert the user to possible errors, which indicate the level of data quality, and guide the user about the appropriate use of the data (Bernhardsen, 2002).

3.4.2 Digital representations

> *A GIS is a computer-assisted system, combined with appropriate infrastructures, resources and management, that acquires, stores, retrieves, transforms, manipulates and displays* ***geographical and related non-geographical data****.*

The previous section gave a brief discussion on the nature of spatial data, and how the features selected from the real world can be represented on a flat surface such as a map or a computer screen. This representation in a GIS can be done using either the raster or the vector model and in some instances a combination of both. This section looks at the processes involved in transforming real-world features into digital spatial features in a GIS. The second part of this section examines the different methods used by the GIS to portray the selected spatial feature. The third part of this section describes the different methodologies employed by different GISs to store and manage spatial and related non-spatial attribute data. Bernhardsen (2002) describes a five-stage process which converts the selected real-world features into map features. These five stages simplify the real world to enable the GIS to represent the real world. These steps are (Bernhardsen, 2002):

Stage 1: The real world

The real world consists of features on the Earth's surface such as buildings, roads, mountains, rivers, woods and others entities which are selected for a specific need (see Figure 3.7). The feature selected is determined by the specific need such as routing a truck has to be routed from point A to B the roads and the various locations of interest.

Stage 2: The real-world model

The real-world model describes the feature in the real world selected for a specific purpose (see Figure 3.7). In the routing example, the selected feature is the road network, the attributes needed are direction, speed and travel time, and the relationships describe how different sections of the road network are related to each other, such as connected sections, overpasses, underpasses or end sections.

Stage 3: The data model

A data model, which is a high-level data structure (Eigenhofer and Herring, 1991; Korte, 2001 and Longley *et al.*, 2001), is used to translate the features described in the real-world model into a format that a computer can use. The road network can be broken down into features such as highways, secondary roads, main roads and country roads depending on the need. For the routing example, only one feature is used, namely roads. Bernhardsen (2002:40) classes features (or objects) into the following broad classes: physically discrete features such as the road example; continuously changing features such as elevation or rainfall; classified features such as soil types; events such as crime incidents; and artificial features to represent the real world, such as a satellite image which is a raster that represents the real world features using reflected radiation values. The feature attributes of roads are road type such as highways and main roads, direction, speed and travel time. To enable the computer to acquire, store, retrieve, display and analyse the features, must be geometrically represented. The geometric representations that can be used are points, nodes, lines, strings, areas (polygons) and raster cells or pixels. Feature relationships are attributes that describe the relationships between features such as connect to, borders on, contained within and topological relationships. During this stage the decision is made whether to represent the data in the raster or the vector model based on the need and/or GIS that is available. Figure 3.7 gives an example of a data model.

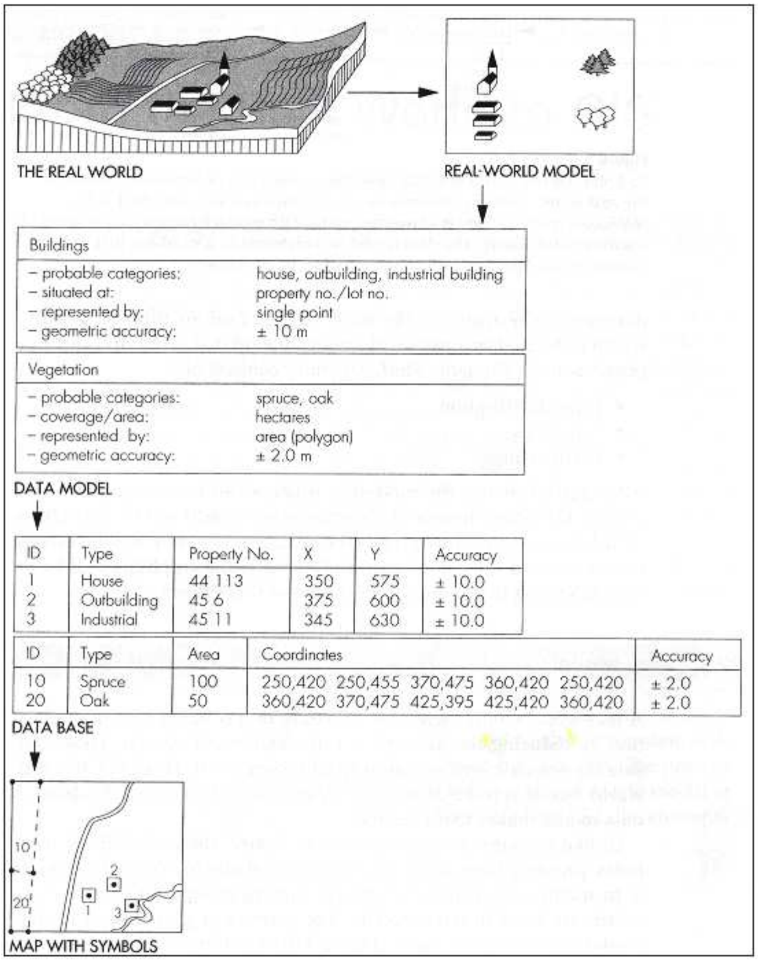

Figure 3.7: From the real world to a map

(from Bernhardsen, 2002:38, Figure 3.2)

Stage 4: Database

Once the data model has been defined, the elements described above must be captured in a database for storage, retrieval, analysis and display by the computer. Figure 3.7 above gives an extraction from the database.

Stage 5: Maps/Reports

The features are displayed on a screen or a paper map represented by symbols. The roads in the routing example will be displayed using the line symbol. The line symbol can be changed to represent road types. The selected route will be displayed by a different line symbol to enable the user to distinguish between the road types and the selected route (see Figure 3.7).

GIS displays the spatial features as two-dimensional representations, namely in X and Y dimensions. The X and Y values are determined by using the process as described in Section 3.4.1. The other two digital representation forms are specialised representations, namely the Digital Elevation Model (DEM) or the Digital Terrain Model (DTM), and three-dimensional (3-D) GIS. A DEM is used to calculate slopes, aspects, contours, watersheds, drainage networks and line-of-sight maps, whereas a DTM is used for visual purposes only. A DTM or DEM is actually a 2.5-D representation where the z value (giving the altitude over an x and y value (coordinate)) is displayed as a surface with different colour codes to give the impression of 3-D, known as hillshading. This surface is created using either pixels in a raster GIS or polygons in a vector GIS known as triangulated irregular networks (TIN). These surfaces are normally displayed on a screen as perspective views (see Figure 3.9) (Weibel and Heller, 1991; Cassettari, 1993; Heywood, 1995 and Longley *et al.,* 2001).

A 3-D GIS is where the feature is displayed as a solid object with width, height and volume as opposed to a 2.5-D display of a surface only. 3-D GISs are complex systems and are used in geological exploration and modelling, environmental monitoring, civil engineering and landscape architecture (Raper and Kelk, 1991 and Cassettari, 1993). Figures 3.8 and 3.9 give examples of 2.5-D and 3-D GIS visualisations respectively.

There are three types of GIS models (methods) that are used to enable a GIS to represent digital data as discussed above. These different models are illustrated using examples of currently available GIS. The first model is the hybrid data model where the spatial data (coordinates and topology) are separate from the attribute data set. The attribute dataset is managed using standard database management systems such as dBase and is linked to the spatial data via an internal software link.

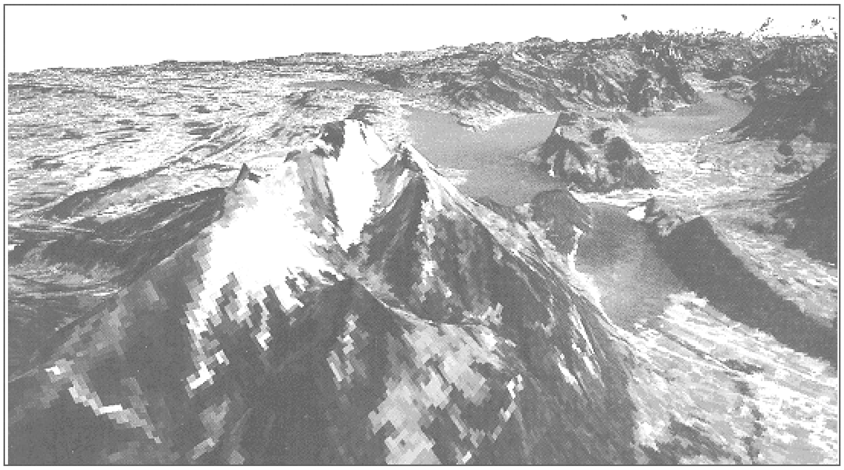

Figure 3.8: An example of a 2.5-D GIS visualisation
(from Weibel and Heller, 1991, Plate 19.2)

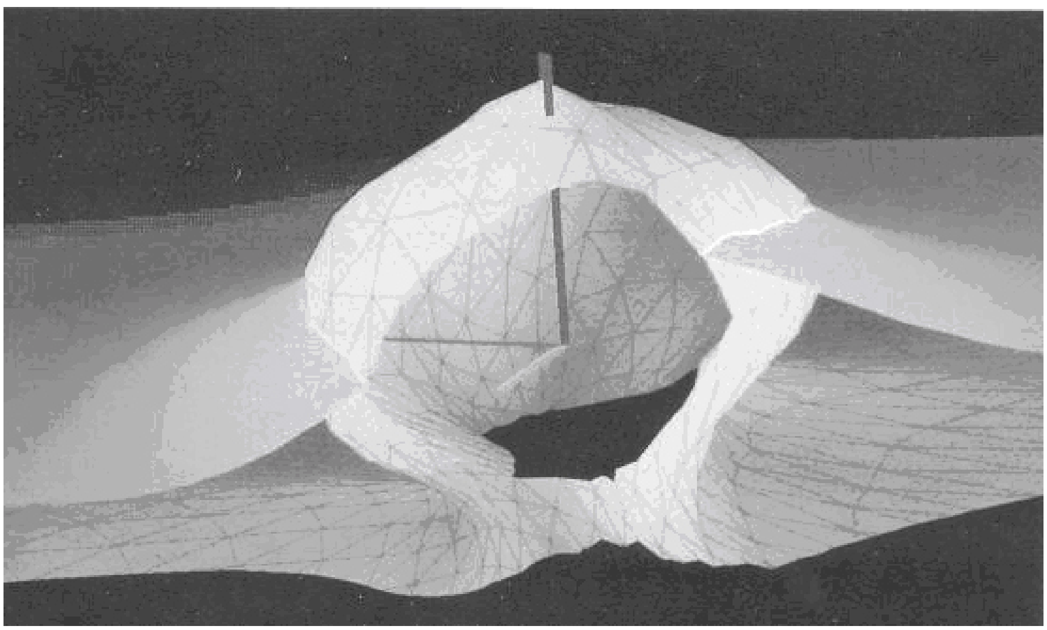

Figure 3.9: An example of 3-D GIS visualisation
(from Raper and Kelk, 1991, Plate 20.2)

ArcGIS from ESRI is an example of such a GIS where the attribute data are stored in a standard dBase (.dbf) file and the vector spatial data (points, lines and polygons) are stored in a shape (.shp) file. The other files, .shx, .sbn and .sbx, are index files used by ArcGIS to access the features as described by the shape files (ESRI, 1998a and ESRI, 1998b). The .prj file gives information on the map projection and map datum used such as Albers Equal Area Conic projection with the WGS84 map datum (ESRI, 2005).

Another example is MapInfo, where the attribute data file structure description is stored in the .tab file, the .dat file is the attribute data file, the .map file contains the spatial vector data, the .id file is used by MapInfo to link the attribute data with the spatial data and the .ind file is the index file which assists MapInfo to find specific features such as a street address, land parcel or vegetation type (MapInfo, 2000).

The second model is the integrated GIS model, where the spatial dataset forms part of the database in which the attribute data are kept. An example of this type of GIS is IDRISI. Both IDRISI's raster (.rst) and vector (.vct) data files contain the spatial data and related attribute data. IDRISI spatial files can also link to other data files (.mdb and .avl) that have additional attribute data related to the spatial data using Database Workshop. The raster, vector and additional attribute data files each have an associated file that contains the metadata about these files used by IDRISI (Eastman, 2003).

The last model is the object-oriented GIS model. Object-oriented GIS is based on the philosophy of object-oriented programming, which aims to present objects in more natural way (Bolstad, 2005). A city, for example, can be defined as object "City" with different spatial and attribute data that describe the object "City". The spatial and attribute data consist of several layers, each layer describing the object "City", such as the city boundary, the street network, reticulation network, water supply network, electricity grid, land parcels, buildings, parks and boreholes. The associated layers are in relation to each other, e.g. the land parcels are within the city boundaries, buildings are within the land parcel and the road is next to or between different land parcels.

Object-oriented GIS also allows relationships between the same or other objects. The object "City" as described above can be related to other cities within the object "Country", or related to other objects such as "Agriculture" or "Mining" within the object "Land Use" (Bolstad, 2005). eCognition is an example of such a GIS.

eCognition is an object-oriented image analysis GIS used to classify remotely sensed images using fuzzy logic to build the rules to segment. This allows the GIS to use different hierarchical levels of image classification as well as using neighbours to assist with the classification. An example is the classification of urban open space and grasslands used for agricultural purposes. The grassland adjacent to or surrounded by urban land use may be classified as *urban green* and not as *agricultural grassland*. If it is classed as urban green, then this will be linked to the object *urban* and not the object *agriculture* (Definiens Imaging, 2001).

Sections 3.4.2 and 3.4.3 discuss the nature and representation of spatial data. From a supply chain and supply chain management point of view, an understanding of the nature of spatial data and how it is represented in a GIS will guide the responsible person with regard to the specific spatial data that will be used by the GIS unit (sourcing of data from internal and external suppliers); the different functions the GIS can perform on the spatial data it uses to manufacture the GIS product; and the formats in which the GIS product can be delivered to the internal or external customer.

3.4.3 Functional issues of GIS

> *A GIS is a computer-assisted system, combined with appropriate infrastructures, resources and management, that* ***acquires, stores, retrieves, transforms, manipulates*** *and displays geographical and related non-geographical data.*

The functionality of a GIS deals with the aspects of the acquisition, storage, retrieval, transformation and manipulation of the data by a GIS (Maguire and Dangermont, 1991; Cassettari, 1993; Korte, 2001, Longley *et al.*, 2001 and Bolstad, 2005). **Data acquisition** is concerned with the capturing, sourcing, transferring, validating and editing of spatial data and their related attribute data. **Data storage** is the storing of the spatial data and their related attribute data in a storage device such as a data warehouse based on selected data structures that are determined by a specific need or purpose (Maguire and Dangermont, 1991 and Heywood, 1995). Three types of data structure are used in GIS, namely tessellations (raster), a vector and a hybrid structure. Tessellations can be regular or irregular, a vector can be unstructured or have topology (intelligent data, which allow e.g. network analysis or allocation of services), and a hybrid structure is a combination of the two (Maguire and Dangermont, 1991; DeMers, 2000 and Bolstad, 2005).

The **retrieval** of spatial data and related non-spatial attribute data is facilitated through the use of indexes as mentioned in the MapInfo example in Section 3.4.2. Indexes of feature geometry allow operations such as the selection of features or the spatial joining of feature attributes (ESRI, 1998b).

Transformation of spatial data is commonly known as coordinate transformation, which allows spatial data that has been captured to be represented in an Earth-based map coordinate system. This allows the data to be aligned with other data layers within a GIS. An example is a map that is being digitised. The digitising tablet has its own coordinate system to enable it to capture data, but the output of the captured data must be in a standard map coordinate system and not that of the digitiser. This transformation of coordinate systems is facilitated through the use of control points. Control points are locations on the map of which the coordinates, as well as the type of map projection used, are known. Before digitising of the map is begun, the control points are selected using the digitising puck and entering the map coordinates at each selected control point. This information includes the map projection, the control points giving the map coordinates (e.g. in degrees latitude and longitude) and the corresponding digitising points giving the digitiser coordinates in centimetres starting at the lower left corner of the digitising tablet. The information is then used to convert the digitised spatial data captured in digitiser coordinates to Earth-based map coordinates for use in a GIS (Bolstad, 2005).

Manipulation is used to create a GIS product to satisfy a specific need. Manipulation activities include, but are not restricted to, the restructuring of data such as the conversion of vector data to raster data and the generalisation of features using specific algorithms for smoothing or aggregation of features.

Generalisation of spatial data is necessary for location and attributes accuracy, consistency and completeness of spatial features displayed on a map. The map (paper or digital) is a model of the real world at a specified scale (1:10 000 or 1:1 000 000), which leads to the loss of details in features, such as the nooks and crannies along a coastline. By using a walking generalisation algorithm to preserve the fractal dimension of a coastline as illustrated in figure 3.10 (Muller, 1991) the general shape of the coast line is preserved.

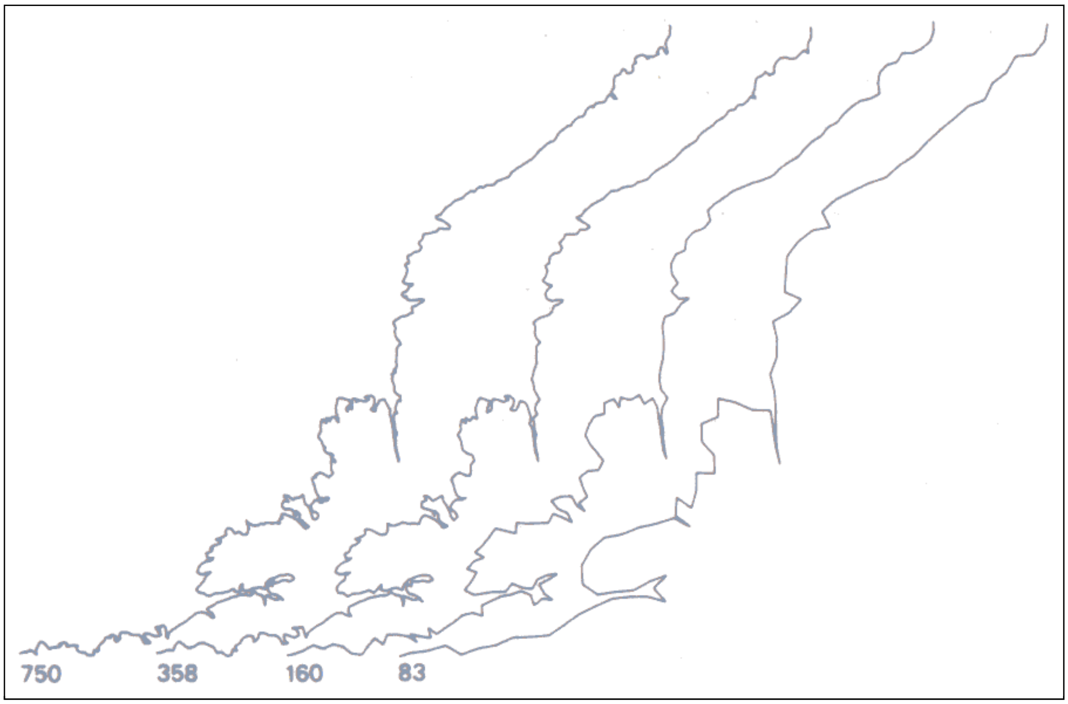

Figure 3.10: Preserving the coastline using fractal dimension preservation

(from Muller, 1991:469 Figure 30.8)

Analysis, which is a special form of manipulation of spatial data, ranges from querying of data, to the integration of different data sources, to complex geostatistical analysis such as Kriging to determine an ore body based on borehole data (Maguire and Dangermont, 1991; Cassettari, 1993; DeMers, 2000 and Bolstad, 2005). One form of analysis in a GIS is the integration of data from various sources to create new information. There are two models for integrating various layers of spatial data and their attributes. The composite map model integrates the various layers and their attribute data into a single map layer and its attribute data. In the geo-relational model, each layer consists of two separate tables: the spatial data of the spatial feature is in one table and has a column that contains data that can be linked with an attribute table that contains all the information describing the spatial feature. This allows more complex analytical procedures to be performed to create new spatial data layers and their attributes. It also allows attribute analysis, where the attribute data are exported for analysis using statistical or other software such as SAS, and the results are imported back into the GIS to be displayed spatially or used in further analyses.

The creation of new spatial data and their related attributes is a two-step approach irrespective of the model used to create the new information. The first step is to remove any inconsistencies in the data. Inconsistencies are caused by using different measurements to measure the same feature, or by using different resolutions, such as the one dataset having a pixel resolution of 30 m and the other a resolution of 10 m. To eliminate the inconsistencies, the data sets have to be resampled first before they can be combined to create a new layer. There are several other causes of inconsistent data, but the above are only examples to indicate the implications of inconsistent data. any such inconsistencies must be resolved before the data sets can be interrelated (the second step) using different GIS operations such as overlays, merging, clipping, geo-statistics and map algebra (Shepherd, 1991; DeMers, 2000 and Longley *et al.*, 2001).

The next concept discussed under functional issues is cartographic modelling. Cartographic modelling is closely linked to the analytic capabilities of the GIS, such as the integration of data from various sources to create new data. Cartographic modelling (also known as map algebra) is the analysis and syntheses of geographical data in a step-wise format. It shows the base data sets (e.g. elevation, roads and soils), intermediate data sets and the final dataset which shows suitable sites for building homes (result) and the different GIS functions required for each step (Figure 3.11) (Bolstad, 2005). Cartographic modelling is based on two conventions.

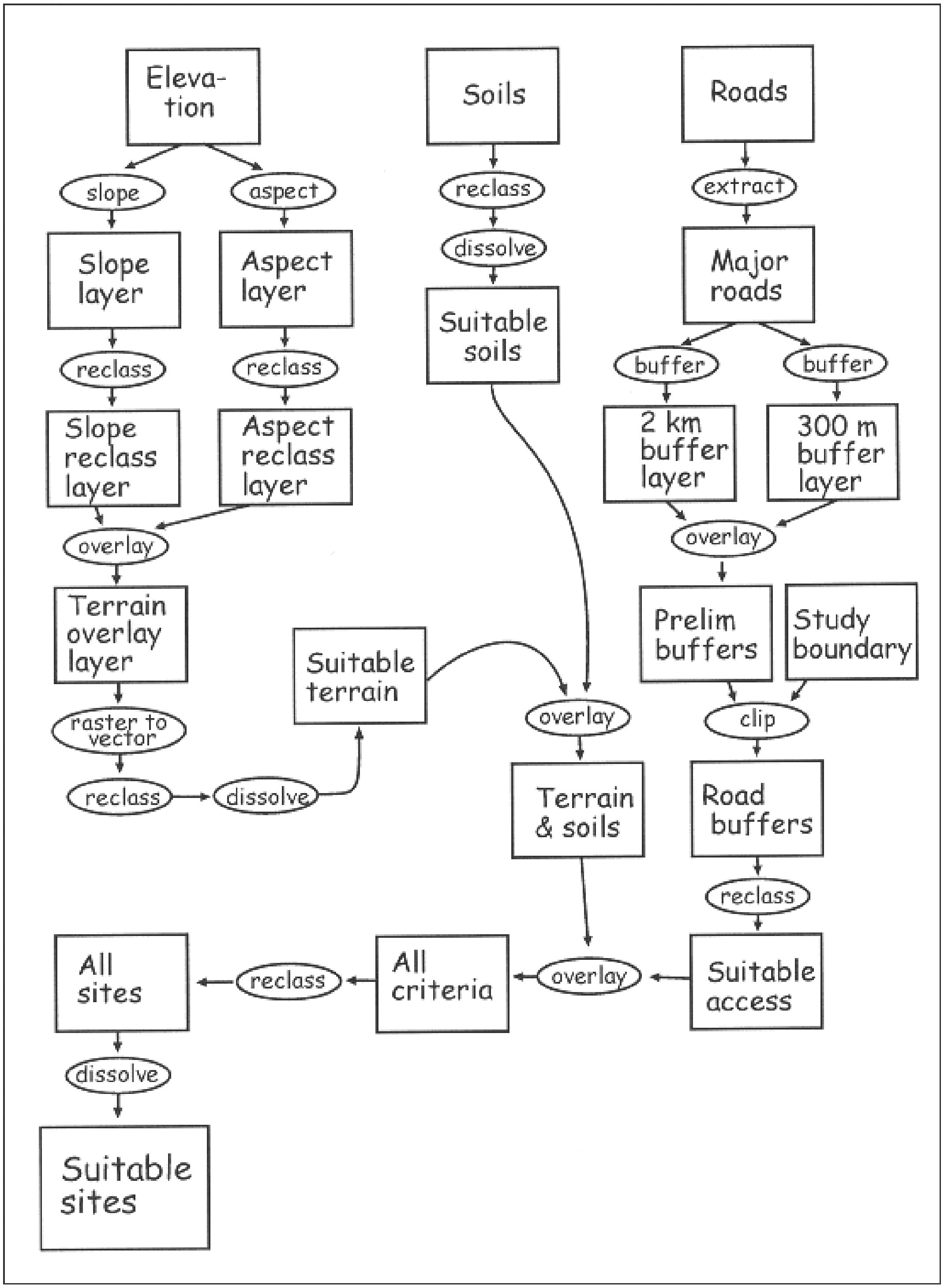

Figure 3.11: A cartographic model to determine suitable sites

(from Bolstad, 2005:445, Figure 13-8)

The first convention is the data convention that governs the way map layers are displayed in terms of labelling, titles, orientation (north, etc.), and resolution of the data (spatial and non-spatial) to name a few. The second convention deals with the processing of the data such as data preparation and the analytical and operational procedures that the GIS can perform to create the answer needed (Tomlin, 1991, DeMers, 2000 and Longley *et al.*, 2001).

GIS is a powerful analytical tool for spatial analysis and it is therefore necessary to develop appropriate spatial analysis methodologies (analytical and operational procedures) to create the required GIS product. Buffering of features, the overlaying of different features and spatial data queries are examples of spatial operations that can be carried out using a GIS. Spatial analysis is based on the application of statistical methods and mathematical modelling such as map algebra. Spatial operations can be used as part of spatial analysis (Openshaw, 1991 and Longley, *et al.*, 2001). Table 3.1 gives a summary of different types of spatial analysis methods that can be used in a GIS to create a GIS product (Openshaw, 1991:390).

Table 3.1: Examples of spatial analysis methods available

Type of geographical data	**Methods of analysis**
Point	Nearest neighbour Quadratic methods
Line	Network analysis and graph theoretical methods Fractal dimension Edge detection
Area	Shape measures Spatial autocorrelation Spatial regression Regionalisation Spatial interaction Location-allocation modelling
Surface	Image processing Bayesian mapping

Openshaw (1991) states that spatial analysis looks at spatial pattern description, such as nearest neighbour analysis, Kriging or spatial autocorrelation. Another example of spatial analysis is the determination of spatial pattern relationships, for example investigating the causes of crime hot spots linked to the location of drug selling points, run down inner city areas, public transport nodes, e.g. bus stops and taxi ranks. These can be modelled using regression analysis or other methods to model and determine spatial associations (Openshaw, 1991). Using the capabilities of GIS discussed above, spatial decision support systems can be developed to assist decision-makers to make better decisions based on improved analysis of spatial data as well as the GIS's capability to do what-if analysis (Densham, 1991 and Longley *et al.*, 2001).

The acquisition, storage, retrieval, transformation and manipulation of the data by a GIS indicates a typical supply chain where data are sourced (acquisition and storage) and a GIS product is created (retrieval, transformation, manipulation and analysis). The GIS product created is stored in the data warehouse or other storage device, from which it is retrieved and delivered to a customer. To enable the GIS user and the customer to visualise the created GIS product, it must be displayed. The displaying of the GIS product is discussed in the next section.

3.4.4 Displaying of spatial data in a GIS

> *A GIS is a computer-assisted system, combined with appropriate infrastructures, resources and management, that acquires, stores, retrieves, transforms, manipulates and* ***displays*** *geographical and related non-geographical data.*

The geographical and related non-geographical data are either displayed in an electronic form or on paper such as maps, tables and graphs (Maguire and Dangermont, 1991). This section deals with the displaying of spatial data in a GIS called visualisation. Visualisation is "*the representation of ideas as images and the issue of the design of images including cartography and computer representation* (Petch, 1998:1)". Before the computer age, visualisation tools to display geographical information were e.g. atlases, road maps, thematic maps showing the distribution of people, economic data such as the Gross Geographic Product in each magisterial district, aviation maps and navigational charts. With the coming of the computer age, computer-assisted cartography was developed to draw maps, which in turn led to the development of GIS. The development of faster computer processors as well as sophisticated computer graphics to provide multi-faceted graphs and maps in two and three dimensions led to the term visualisation in scientific computing (ViSC) (Buttonfield and Mackaness, 1991; Petch, 1998 and Longley *et al.*, 2001).

According to Petch (1998) and Longley *et al.* (2001) ViSC is designed to assist the user of the GIS to eliminate uncertainty in the interpretation of the image during the creation of a GIS product. Thus:

> *"ViSC allows users to interpret, validate and explore their data in greater detail than was possible hitherto"* (Longley *et al*., 2001).

Using ViSC, the following questions can be asked about spatial and temporal analysis (Longley *et al.*, 2001:264):

- Where is…?
- What is the location…?
- What is the spatial relation between …?
- What has changed since….?

The interaction between the user and the computer to enable ViSC to find answers to the above questions is done via WIMP interfaces (windows, icons, menus and pointers) as shown in Figure 3.12 (Longley *et al.*, 2001).

Other display issues are concerned with computer cartography, namely the placement of text in a computer-generated map (Freeman, 1991; Cassettari, 1993 and Petch, 1998) and the generalisation of spatial data (Muller, 1991).

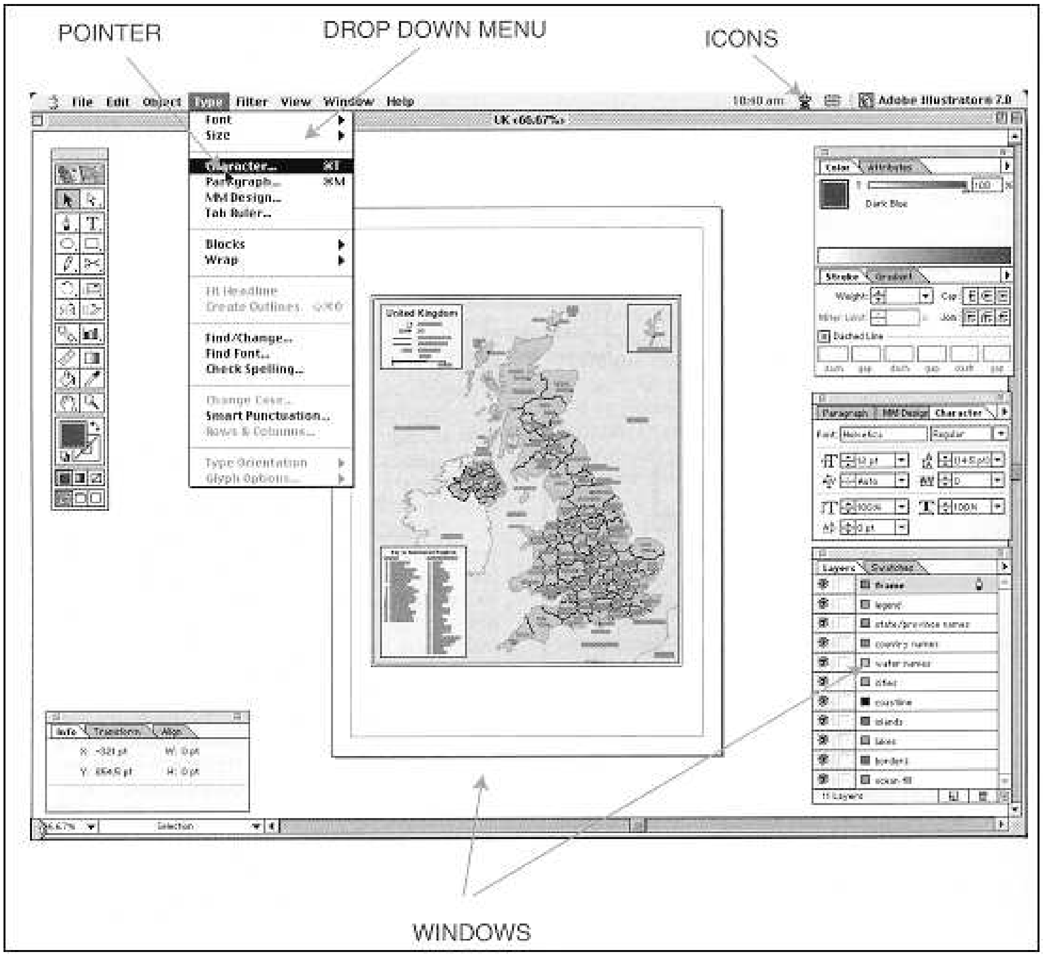

Figure 3.12: WIMP (windows, icons, menus and pointers) environment
(from Longley *et al.*, 2001:266, Figure 12.16)

There are several methodologies and approaches to generalise features of the Earth's surface for display purposes, such as geometrical generalisation where the feature is simplified when the scale changes as discussed in Section 3.4.3, and the conceptual generalisation where features of the real world are selected and then classified into different groups, such as cities, roads, airports and churches, and displayed as symbols. An example of a map using different symbols is a roadmap (Figure 3.13) as published by the Automobile Association of South Africa (AA). The roadmap for the Western and Northern Cape published by the AA uses different line sizes and colours to indicate road types, e.g. national and link roads, as well as different point symbols to indicate towns, toll roads, airports, rest camps and border control posts. The town symbol is a circle. Different types of circles indicate the types of facilities available in a town such as accommodation and a garage (for servicing a motor vehicle and selling fuel) or accommodation and fuel (petrol) or petrol only (AA, 2002). Figure 3.13 shows a section of the Western and Northern Cape roadmap.

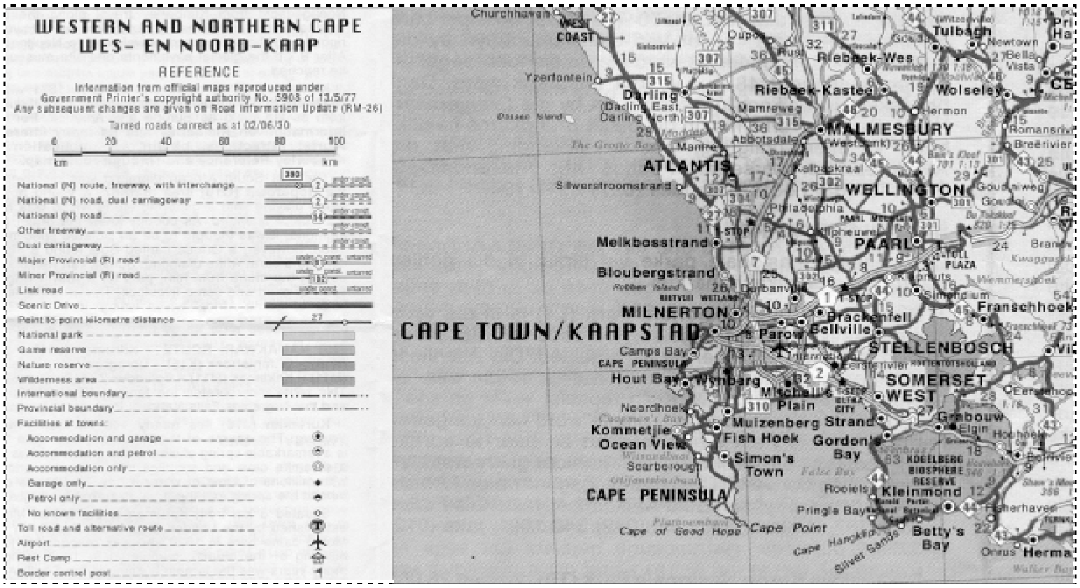

Figure 3.13: Section of the Western and Northern Cape roadmap published by the Automobile Association of South Africa

(AA, 2002)

A catastrophic change occurs when a feature can no longer be simplified using geometrical generalisation, such as fractal dimension preservation and changes into conceptual generalisation, i.e. the feature now becomes a symbol (Muller, 1991). An airport on a 1:10 000 scale map is shown in detail (runways, apron and building outlines), but at a 1:500 000 scale map of the airport's location is now shown by an aeroplane symbol. The last principle with regard to GIS is the operational issues in GIS.

3.4.5 Operational issues in GIS

The following operational issues in GIS mentioned by Maguire *et al.* (1991) are: the implementation of a GIS, legal aspects regarding GIS, and the exchange of spatial data and associated standards. There are several approaches to describe the introduction of a GIS into an organisation. Clarke (1991) and Longley *et al.* (2001) call the introduction of a GIS in an organisation the acquisition process of which the implementation of the GIS forms part of the acquisition process as shown in Figure 3.14. Other authors who discuss the introduction of a GIS into an organisation such as Huxhold and Levinsohn (1995); Korte (2001); and DeMers (2000) see the acquisition of a GIS as part of the implementation process. For the purpose of this study, the introduction of a GIS into an organisation is seen as the implementation of a GIS in an organisation.

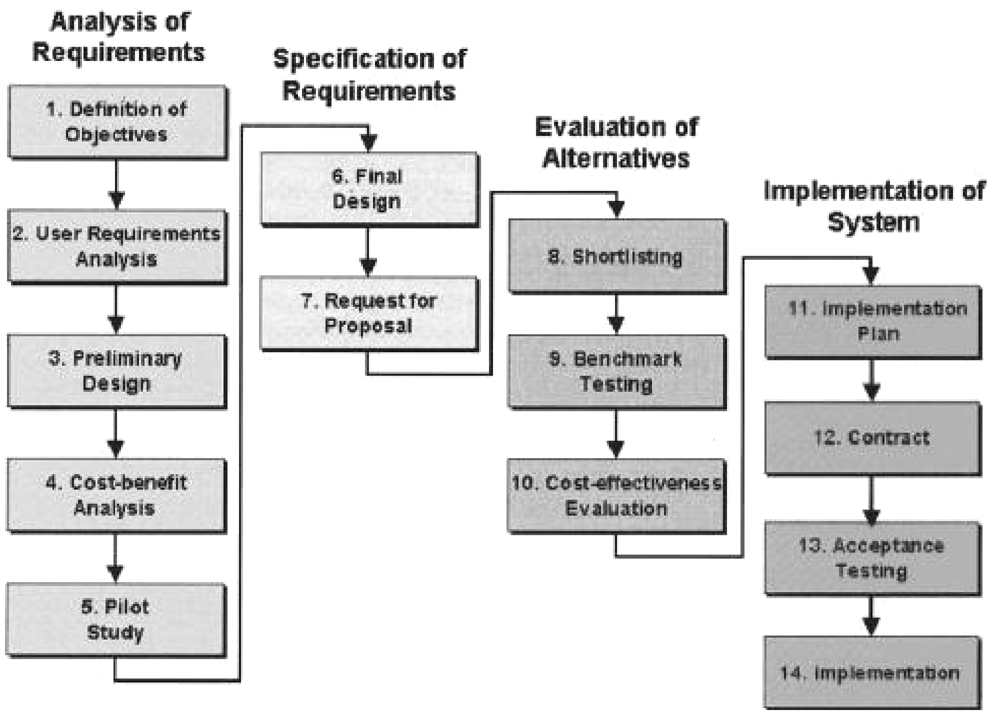

Figure 3.14: General model of GIS acquisition process

(from Longley *et al.*, 2001:399, Figure 18.2)

3.4.5.1 Implementation of a GIS

The implementation process of a GIS into an organisation for the purpose of this study is done in eight stages. The first stage is the establishment of the implementation team. The other seven stages are: the planning of the GIS; user requirement analysis; cost-benefit analysis; design of the GIS; system acquisition and development of the GIS, implementation of the GIS; and training of the GIS users.

The establishment of a GIS implementation team is necessary to guide the implementation process. An implementation team consists of a GIS champion, who has the vision and knowledge to implement a GIS in the organisation and is well known in the organisation. The GIS champion is assisted by an executive sponsor, who reports directly to executive and the core team. The core team consists of knowledgeable people who have leadership skills and a good understanding of the different functions within the organisation that can benefit from the implemented GIS (Bolstorff and Rosenbaum, 2003).

The implementation team, in consultation with different line function managers, develop a provisional GIS plan. This planning stage of the GIS involves where the GIS is to be placed in an organisation, i.e. at executive level or as a line function; the scope of the GIS, which is linked to the strategy and mission of the organisation; the staff issues; type of GIS; training; data; database development; data maintenance; and an outline of the implantation process, including timelines (Obermeyer and Pinto, 1994; Huxhold and Levinsohn; 1995, Somers, 1998 and Korte, 2001).

Once the GIS plan has been communicated to the organisation, the next step in the implementation process is to establish the user requirements analysis, also known as a user needs study (UNS) (Reeve, 1998). A user requirement analysis, according to Huxhold and Levinsohn (1995:87), is the assessment of "*the needs of the organisation, determining the workings of various business units, their information needs and an assessment of how GIS could be applied to the identified work*." This can be done through interviews, questionnaires, the observation of current work processes and the analysis of information and data flows within the organisation (Reeve, 1998). Based on the results of the UNS, a conceptual model of the GIS is developed.

The conceptual model of the GIS that will be implemented in the organisation will be used as the basis of the cost-benefit analysis. The cost-benefit analysis includes both tangible and intangible costs and benefits of implementing a GIS. Tangible costs and benefits can be clearly defined in monetary values, whereas intangible costs and benefits are influenced by soft issues such as the self-esteem, morale and job satisfaction that will be experienced by the staff when a GIS is implemented in the organisation (Reeve, 1998 and Bernhardsen, 2002).

The cost-benefit analysis is normally seen as a Stop-Go function of the implementation process, which determines whether to proceed with the implementation or not (Bernhardsen, 2002).

Based on the results of the cost-benefit analysis, the organisation decides to proceed with the implementation of the GIS. This next stage is the design of the GIS based on the UNS and the conceptual model of the GIS, in other word, a detailed design of the GIS that will be implemented in the organisation. The design is a comprehensive GIS which takes into account the user-computer interface and the various technical subsystems of the GIS that will effectively and efficiently meet the functional requirements of the different users (Huxhold and Levinsohn, 1995 and Reeve, 1998).

Once the design has been finalised, the system must be acquired and developed for implementation throughout the organisation. During system acquisition, staff has to be trained to use the GIS once it has been implemented (Huxhold and Levinsohn, 1995 and Bernhardsen, 2002). The acquisition and development of the GIS based on the design should include the following activities (Bernhardsen, 2002:361):

- *Pilot project.*
- *Design requirements.*
- *Choice of hardware and software.*
- *System implementation.*
- *Technical database design.*
- *Creating databases.*
- *Operation and maintenance.*
- *Safekeeping and security.*
- *Evolving new applications.*

Once the GIS has been acquired, developed and tested on basis of the above activities, it has to be revised to eliminate any problems before it is implemented throughout the organisation. To enable the success of the implementation, a detailed implementation plan must be communicated throughout the organisation. The plan must be flexible to accommodate any critical issues that may have been missed during the acquisition and development phase (Huxhold and Levinsohn, 1995 and Somers, 1998).

The last phase of implementing a GIS in the organisation is the proper training of the staff to ensure the success and use of the GIS. Although it is regarded as the final phase of implementing a GIS, training forms an integral part of the implementation process (Huxhold and Levinsohn, 1995; Somers, 1998; Korte, 2001; Bernhardsen, 2002 and Farrant, 2006). Implementing a GIS in an organisation will invariably lead to legal implications which must be taken into consideration to ensure compliance. The legal aspects are elaborated upon in the next section.

3.4.5.2 The legal aspects of a GIS

The discussion of the legal aspects of a GIS is based on the literature, but with the emphasis on laws applicable in South Africa. The following acts are relevant to a GIS in South Africa as identified by South African Council for Professional and Technical Surveyors (2006):

- Spatial Data Infrastructure Act, 2003 (Act No. 54 of 2003) (GG, 2004)[2].
- Copyright Act, 1978 (Act No. 98 of 1978) as amended, excluding Sections 8, 9, 10, 14, 16, 17, 18, 28, 31, 32, 33, 34, 38, 40, 42, 45, 46 and 47 (Juta, 2006a).
- Legal Deposit Act, 1997 (Act No. 54 of 1997) as amended, only Sections 1, 2, 3, 4, 5, 6, 9 and 10 (GG, 1997).
- National Archives of South Africa Act, 1996 (Act No. 43 of 1996) as amended, only Sections 1, 3, 11, 12, 13 and 14 (President's Office, 1996).
- Promotion of Access to Information Act, 2000 (Act No. 2 of 2000) (GG, 2000).

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[2] The abbreviation GG is used for Government Gazette in the reference. During the discussions only the Act will be mentioned and not the reference.

- SA Geographical Names Council Act, 1998 (Act No. 118 of 1998) as amended, only Sections 1, 9 and 10 (Juta, 2006b).
- Statistics Act, 1999 (Act No. 6 of 1999), only Sections 1, 3 and 17 (GG, 1999).
- Electronic Communication and Transaction Act, 2002 (Act No. 25 of 2002), only Sections 1, 2, 11, 12, 14, 20, 42, 43, 44, 45, 46, 50, 51, 53, 54, 55 and 56 (GG, 2002).

The South African Spatial Data Infrastructure (SASDI) is, according to Act No. 54 of 2003, a mechanism to facilitate the capture of spatial information through cooperation between different state departments and related organisations to: ensure that the captured spatial information is properly managed and maintained in line with the appropriate standards; encourage the use and sharing of spatial information in decision-making; and to create an environment in which spatial information can be captured, maintained and shared in a coordinated and cooperative manner, including the adherence to quality procedures and the relevant standards. SASDI was also established to: minimise duplication of the capturing of spatial information; promote universal access to spatial information in accordance with the Promotion of Access to Information Act of 2000; and facilitate the protection of copyright of the spatial information that has been collected by the State, as well as any value addition to the spatial information by the State according to the Copyright Act of 1978 as amended. The objectives of SASDI are given in Section 3 (2) (a-g) of the Act.

The Copyright Act of 1978 provides for the protection of the copyright of spatial information that has been created either by collecting it or through value addition of existing data. The copyright will only reside in the value-added part whereas the copyright of original spatial information belongs to the creator of the original set. It is interesting to note that the USA Copyright Act of 1976 specifically refers to a map as “pictorial, graphic and sculptural works” (Korte, 2001:254), whereas the South African Copyright Act of 1978, as amended, does not specifically refer to maps as such. The assumption can thus be made that a map is an artistic work that is published either in paper or any of electronic format including a GIS.

The Legal Deposit Act of 1997 deals with any publication that has been made by a state organ or a parastatal or other public registered institution to be deposited at a designated place for safe-keeping. The National Archives of South Africa is such a designated place and is governed by the National Archives of South Africa Act of 1996. According to these acts any spatial information collected and created by the above institutions should make a copy available for safe-keeping at a designated place.

The purpose of the Promotion of Access to Information Act of 2000 is to allow an individual to exercise his/her constitutional right to access any record or information held by the state or private entity. Access to information can be limited by justifiable means, e.g. to protect a person’s privacy or commercial confidentiality, or when access could undermine effective, efficient and good governance (Chapter 3, Section 9 (b)). The Act also describes the manner in which information can be requested and gives guidelines on how and in what form to grant or deny the request. The guidelines are given for both public and private bodies (Part 2 and 3 of the Act). This is also applicable to spatial information. Part 4 of the Act gives guidelines for a requestor to appeal against a refusal to provide the information.

The South African Geographical Names Council Act of 1998 deals with the definition of a geographical name is, i.e. whether it is linked to any terrestrial feature, which can be either physical (e.g. mountain or river) or cultural (e.g. town, nature reserve or farm) as well as whether this feature may or may not be populated (Section 1 of the Act). The Act further gives an indication of the standards that must be followed with regard to geographical names, as well as guidelines on the workings of the committee regarding to approval and revision of geographical names (Sections 9 and 10 of the Act). When naming features in a GIS, the latest geographical names should be used as promulgated in the Government Gazette, such as Bela Bela, formerly Warmbaths, or Polokwane, formerly named Pietersburg.

The part of the Statistics Act of 1999 applicable to GIS deals with the official statistics, which are used to aid decision-making, planning and/or monitoring of decisions and planning (Section 3 (1)). Section 3 (2) describes the need for confidentiality and the criteria that official statistics have to adhere to in order to be current and accurate. Section 17 of the Act deals with the confidentiality of data on people and entities, and when and how the information can be disclosed to another person and what the duties are of the person to whom the data is disclosed, with regard to publishing results. The GIS community that works with official statistics or other data collected about individuals must keep the Act in mind when disclosing the gathered data so as not to compromise the confidentiality of an individual or entity.

The Electronic Communication and Transaction Act of 2002 guides and regulates access to electronic communication and transactions, the environment in which electronic communications and transaction are made (safe, secure and effective), as well as the effective use of the .za domain name space (Section 2 of the Act). This applies to GIS as well, since spatial information or data are sent from one location to another via a LAN, WAN, intranet or the Internet. Some GIS units may sell spatial information or data on-line (e-Commerce). Chapter 7, Sections 42 to 49, of the Act deals with the protection and the rights of the consumer when engaging in e-Commerce. Chapters 8 and 9 of the Act deal with the protection of personal information, namely a person's or company's information which is transmitted to and resides in the e-Commerce site such bank account details, etc. (Chapter 8), and the protection of critical databases (Chapter 9). Critical databases according to the Act are those databases of importance to national security or the economic and social well being of the citizens of South Africa (Section 53 (a) of the Act).

According to Korte (2001:248) the following three principal types of legal liability are applicable to GIS:

- Contractual liability, such as the breaching of contractual agreements or reneging on warranties given (Onsrud, 1999). According to Onsrud (1999) there are two types of warranties, namely expressed and implied warranties. The former is the deliberate expression that the spatial information or data will conform to that promised, a description of what the data will be, or if a sample was produced, that the whole dataset will conform to the sample. An implied warranty implies that the information or data can be sold or that it can be used for a specific purpose.

- Statutory liability is compliance to the different acts as discussed above. Section 21 of the SASDI Act states that "no person is liable for anything done in good faith in the exercise or performance or purported exercise or performance of any power and duty in terms of this Act". It is up to the contracting party to prove non-compliance to the SASDI Act.
- Tort liability with respect to spatial information or data refers to a GIS unit disseminating misleading or inaccurate spatial information or data and invasion of privacy (see also the Statistics Act of 1999). Other examples of tort liability are negligent or fraudulent misrepresentation, such as neglecting to inform the client of the lack of certain skills or misleading the client about specific skills that the GIS unit does not have, and not complying with contractual agreements owing to the lack of specific skills (Onsrud, 1999).

The above paragraphs discussed the legal issues regarding GIS. The previous section discussed the acquisition of a GIS and its implementation in an organisation. From a supply chain and supply chain management point of view the implementation of a GIS indicates that resources are available to create a specific GIS product. Examples of resources are GIS software, GIS hardware (PCs, digitising tablets, printers, plotters, data warehouses and servers) and trained staff. The legal aspects are concerned with the regulatory requirements that have to be taken into account when a GIS product is manufactured and delivered to a client. According to the SCOR model, the legal aspects are part of the supply chain enablers. GIS products are commodities that are bought by the GIS unit or sold and delivered to customers by the GIS unit. Thus GIS products have to comply with certain standards before being sourced or delivered.

3.4.5.3 GIS standards and the exchange of spatial information or data

According to Guptill (1991), Cassettari (1993) and Bernhardsen (2002), standards are developed to ease the movement of spatial and non-spatial data between systems and users. Standards provide a common language that is understood by the different GIS users and are used to ensure that the spatial and non-spatial data adhere to certain quality criteria stipulated. There are normally two types of standard, namely an international standard developed by the International Organization for Standardization (ISO) and local (national) standards. The latter are in most instances derived from the applicable ISO standards.

The ISO 19100 suite of standards was developed for the standardisation of geographic information. They include: the development of a reference model to enable the user to understand the conceptual model used for developing the standards (ISO 19101); the standard for spatial referencing by coordinates which allows easy transfer of spatial data, including the reference datum used (e.g. WGS84); the coordinate system used (Geographic Latitude and Longitude) between different GIS systems (ISO 19111); and ISO 19139 which gives the XML schema for metadata known as the **s**patial **m**etadata e**X**tensible **M**ark-up **L**anguage (smXML) to exchange metadata as required by ISO 19115 between different systems (Cooper, 2006). Appendix A gives the full ISO 19100 standard suite as developed thus far. The only other standard that is used by the GIS community is ISO 6709 for the "representation of latitude, longitude and altitude for geographic point locations." The different ISO 19100 standards are developed in such a way that geographic information has to fulfil a set of minimum requirements to adhere to specific standards. These requirements are indicated in the standard by an "M" for mandatory. The other requirements are optional and are marked as "O". For metadata, the file name, the abstract describing the data set, the spatial reference system and the dataset language are examples of mandatory requirements. Two examples of optional information are an alternative title for the dataset and a document reference giving the sources of additional documentation about the dataset (Bernhardsen, 2002). An interesting fact about the ISO 19100 suite of standards is that they are the first

ISO standards to use the UML (Unified Modelling Language) application schema to model the standard, which gives a formal description of the data structures and content of the standard (Bernhardsen, 2002 and Cooper, 2006). Figure 3.15 gives an example of a UML model used to model metadata application information (Standards South Africa, 2004). The UML approach is used in the SANS 1878 core metadata standard for South Africa (Standards South Africa, 2004b). South Africa has a representative on the ISO 19100 standards committee, known as ISO/TC211 (Cooper, 2006).

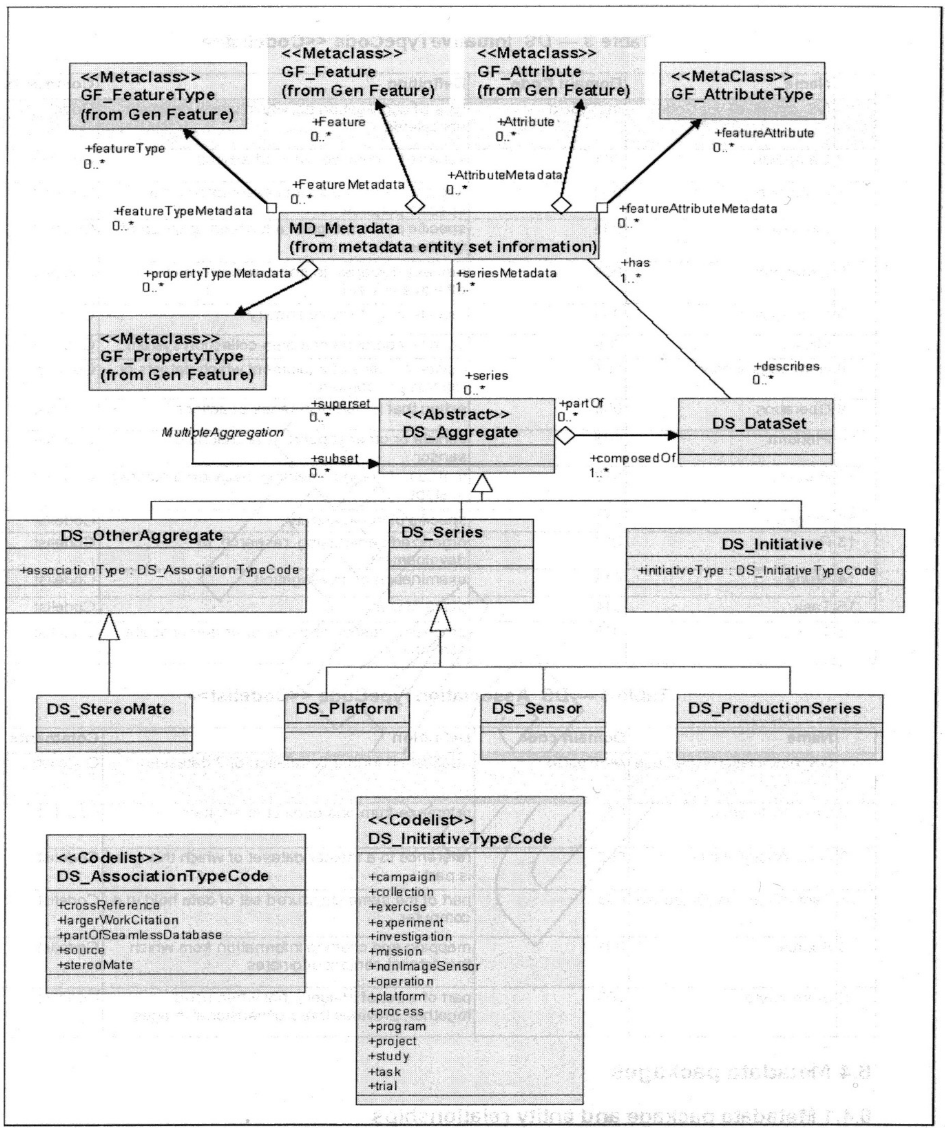

Figure 3.15: An example of a UML model

(from Standards South Africa, 2004:16, Figure 3)

Local or national standards are standards developed by a country based on the ISO standards. In some instances the local standards provide an input for the ISO standards, such as the metadata standard developed by the Federal Geographic Data Committee (FGDC). The Open GIS Consortium (OGC) is an organisation which works on open solutions to enhance the interoperability of geographic information between different GISs and has a strong impact on the development of the standards by ISO (Bernhardsen, 2002).

Standards South Africa, a division of the South African Bureau of Standards (SABS), developed the following four South African national standards based on the ISO standards:

- SANS 1876:2005 - Feature instance identification standard. This standard was developed to specify the rules to identify unique feature instances that are captured in core data sets with the aim of standardising these unique identifiers to enable the integration and linking of disparate data sets as well as sharing of these different data sets . This identifier is known as the South African unique identifier (SAUID) (Standards South Africa, 2005). According to Standards South Africa (2005:3), the SAUID has the following characteristics:

    - *The SAUID shall be unique, permanent and not reused.*
    - *The feature instance need only be unique within the feature group.*
    - *The SAUIDs are for identifying feature instances and not their spatial attributes (i.e. not their geometrical representation).*
    - *The SAUID is assigned to the feature instance, not to the owner or the political boundary in which it is situated.*
    - *No spaces, hyphens or other edit characters shall be used in the SAUID.*
    - *All letters in an SAUID shall be taken from the Roman alphabet and shall be in capital letters.*
    - *The SAUIDs shall only be used for publicly accessible geographical data.*

The standard also gives guidelines on who is responsible for the maintenance of the SAUIDs as well as the allocations of these identifiers.

- SANS 1877:2004 – A standard land-cover classification scheme for remote-sensing applications in South Africa. This standard sets a predetermined framework for remotely sensed data that is developed for land-type classifications to ensure consistency and conformity of map data that are produced by a variety of spatial data producers (private or public) (Standards South Africa, 2004a). This classification system is based on three hierarchical levels of detail. These levels according to Standards South Africa (2004:5) are:

    - *Level 1: 12 broad land-cover types that can be identified of high-resolution (pixel size 30 m or finer) satellite imagery, such as Landsat TM and SPOT, without the use of ancillary data.*
    - *Level 2: 23 subtypes that can be identified from remotely sensed data, without the use of ancillary data, if the data format is suitable (i.e. digital, print scale, season, band combinations, etc.).*
    - *Level 3: flexible, user-defined subcategories developed by individual planners, remote-sensing analysts, etc., specific to their own requirements or resource management disciplines, beyond the scope of this standard. It incorporates subtypes defined with the use of additional non-remotely sensed data, such as edaphic or climatic parameters (i.e. GIS modelling), or the linkage of land-use parameters (e.g. agricultural management practices or intensities: "subsistence-level temporary crops").*

An example of the above is:

Level 1: Forest and woodland

Level 2: Forest, woodland or wooded grassland

Level 3: e.g. conservation (land use) or communal grazing (land use)

- SANS 1878:2004 (Draft) – South African spatial metadata standard, Part 1: Core metadata profile. The core metadata standard is based on the ISO 191115 metadata standard. The objective is to provide a structure to describe geographic data in a standard format for easy transfer and usability (Standards South Africa, 2004b). The metadata *provide information about the extent, quality, spatial and temporal schema, spatial referencing and distribution of geographic data* (Standards South Africa, 2004b:7). This part of the standard gives the core metadata for geographic data sets, including which fields are mandatory, conditional or optional. According to Standards South Africa (2004b), a mandatory field indicates compulsory entry of information. Conditional fields are those fields that have alternative ways to enter the same information to describe, for example, spatial resolution such as pixel size (30 m) and scale (1:50 000 or 2 cm = 1 km), of which one of these choices has to be entered. Optional fields are those fields that contain additional information that describes the geographical data set. The following core metadata elements are given by this standard (M = mandatory, C = conditional and O = optional) (Standards South Africa, 2004:14):

    - Data title (M)
    - Dataset reference date (M)
    - Dataset responsible party (M)
    - Geographic location of the dataset (by four coordinates (e.g. bottom left and top right coordinates) or geographic identifier such as a province or magisterial district) (C)
    - Dataset language such as English or Afrikaans (M)
    - Dataset character set such as the ASCII code set (C)
    - Dataset topic category such boundaries or transportation (M)
    - Spatial resolution of the dataset (see above) (C)
    - Abstract describing the dataset (M)
    - Distribution format, e.g. ESRI shape file or ASCII Grid (M)
    - Additional information for the dataset (vertical and temporal (O)
    - Spatial representation type for raster and vector data such as pixel size, point line or polygon (C)

- Reference system such as the projection and reference ellipsoid used (C)
- Lineage statement that gives information on the source(s) of the dataset (M)
- On-line resource where, the name of and how the metadata can be accessed on-line (C)
- Metadata file identifier (M)
- Metadata standard name (C)
- Metadata standard version (C)
- Metadata language (M)
- Metadata character set such as the ASCII code set (M)
- Metadata point of contact (M)
- Metadata date stamp indicating when the metadata have been created (M).

SANS 1878:2004 is currently only a committee draft proposal and should soon be implemented as a standard in South Africa.

- SANS 1880:2003 – South African Geospatial Data Dictionary (SAGDaD) and its application. SAGDaD contains 80 feature types from which users and/or creators of spatial data can construct their own classification system (Standards South Africa, 2003). A feature type of geographical features can be described as a class of geographical features with common characteristics, such as land use. A nature reserve is an example of land use, which can consist of different geographical features that describe a conservation area with its unique attributes, such as wild life, plants, water features, etc., but the common characteristic is that it is a nature reserve in which the above features occur. A nature reserve is grouped under the heading "recreational land use" The feature type "land use" is described in the SAGDaD as follows (Standards South Africa, 2003:44):

  Code: 36
  Name: Land use

Definition:

An area with an identified, homogeneous human activity, in terms of utilisation, impacts or management practices.

Aliases:

Attribute: Enumerated type

Values:

1. Unknown – The use of which is unknown.
2. Undeveloped land – Land that has not been developed.
3. Unclassified urban area – Urban land that has not been classified further. This includes mixed urban land use.
4. Residential land use – Land used for residential purposes.
5. Commercial land use – Land used for commercial purposes (e.g. trade and services).
6. Agricultural land use – Land used for agricultural purposes.
7. Public service land use – Land used by national, provincial or local government.
8. Transportation land use – Land used for transportation infrastructure and nodal points.
9. Industrial land use – Land used for industry.
10. Cultural land use – Land used for cultural activities.
11. Recreational land use – Land used for the refreshment of one's mind or body through diverting activity.
12. Informal land use – Land used in an unstructured manner or for a purpose for which it was not zoned.

SANS 1883 – National Address Standard: This standard is currently in a working draft stage, which looks into standardising different address types to enable the proper exchange and geocoding of South African addresses.[3]

The above paragraphs give an overview of the ISO as well as the South African standards that are applicable to spatial data to enhance the movement and

[3] The student is a member of the Working Committee of SANS 1883.

sharing of spatial data. The next few paragraphs discuss the different spatial data transfer formats to enable the actual movement of data between users.

According to Berhardsen (2002), the different GIS software packages on the market still have their own individual data formats for handling the geometric data and related attribute data, although there are currently strong moves from industry to ensure interoperability between the different GIS software through the activities of the Open Geospatial Consortium (OGC). It will be some time before that goal is achieved. To enable the transfer of data between different users ISO, specifies that the spatial data should be encoded using XML (see ISO 19137 for the metadata part of spatial data). The data model must be described in UML and the encoded data in XML. To enable the movement of geographic (spatial) data, the OGC has developed GML (Geographic Mark-up Language) for the exchange of simple features (Bernhardsen, 2002).

Currently there are two different exchange standards used to transfer data between different GISs, namely industry standard formats and standard formats developed by different countries. Examples of the latter are the Spatial Data Transfer Standard (SDTS) from the US Geological Survey (USGS) (Bernhardsen, 2002) and the National Exchange Standard developed for data exchange in South Africa (Cooper, 2006). The following are examples of the most widely used industry standard data formats that are used to exchange spatial data:

- ESRI shape format
- Intergraph's SIF format
- USGS Digital Line Graph (DLG) format
- MapInfo MID/MIF format
- ASCII Grid
- GeoTIFF
- MrSID
- ERDAS IMG file format.

Most GIS software has the capability of translating different GIS formats to their inherent spatial data format. When translating the spatial data from one format to another, caution should be exercised since translation errors may occur, which could cause either attribute data or geometric data errors. It is good practice first to validate the dataset after translation before using it for whatever application. Berhardsen (2002) advocates the use of industrial standard formats to exchange data on a national level until the ISO and OGC standards have been completed and implemented.

This section discussed the operational issues of implementing a GIS in an organisation, the legal aspects regarding GIS and the various standards that are applicable when using a GIS. The next section gives several examples of the application of implemented GISs to illustrate the wide range of GIS applications, such as facilities management, responding to disasters as well as the possible use of supply chains and supply chain management during GIS product creation in these different applications. The latter is illustrated using the Supply-Chain Operations Reference model as discussed in Section 2.5.2.

3.5 GIS Applications

3.5.1 Introduction

Section 3.3 discussed the definitions of a GIS as well as the three main components of a GIS, and Section 3.4 discussed the principles of GIS. The application for which the GIS will be used governs the type of GIS required, ranging from a desktop GIS, with limited GIS functionalities to an enterprise-wide GIS system, which has advanced geoprocessing functionalities. Owing to the ever-changing environment in which GIS units have to produce their products, GIS developers such as ESRI are developing scalable GIS products to ensure seamless expansion. Figure 3.16 shows the ArcGIS System which is available from ESRI. In this section several applications of GIS are discussed, and the data flow is examined, i.e. suppliers to the GIS, transformation of the data using GIS into a product which is then made available to the customer/end user.

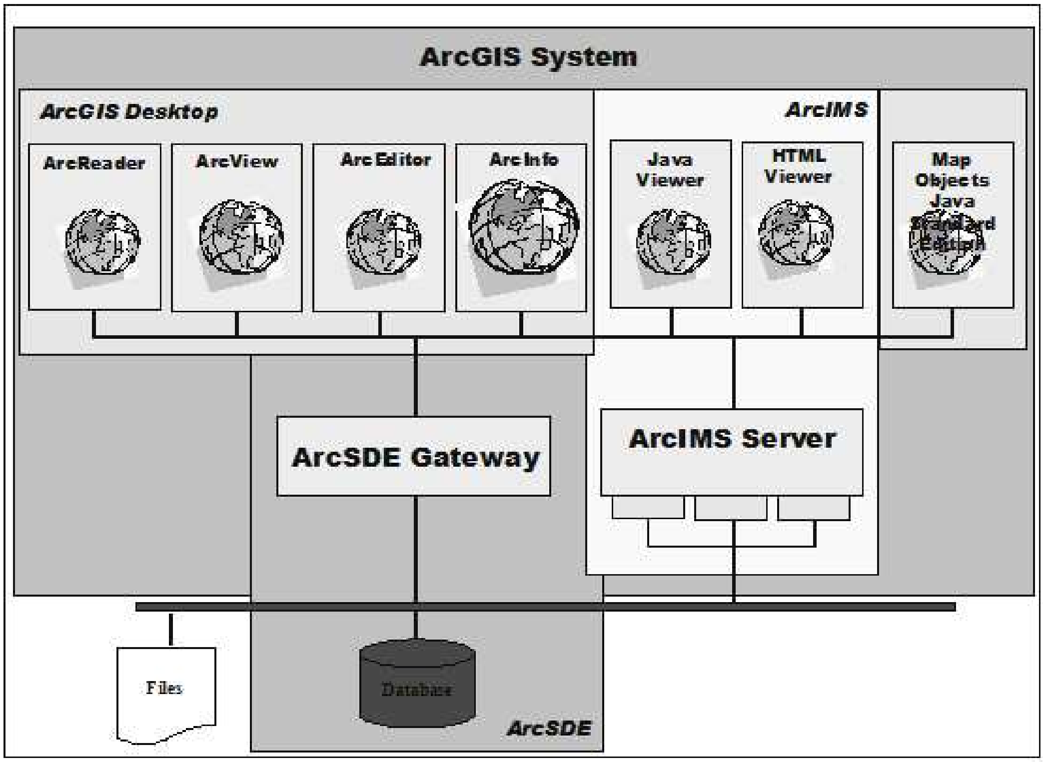

Figure 3.16: The ArcGIS system

(ArcGIS System, p 1: *What is ArcGIS?* ESRI, 2002)

3.5.2 Examples of GIS applications

In this section several examples of GIS applications, although not an exhaustive list, are discussed. The wide variety of GIS applications are demonstrated that occur in practice, and a brief overview is given of how supply chains and supply chain management can be used in these applications.

3.5.2.1 Disaster and risk management

"This stuff saves lives" – Alan Leidner, Director, Citywide GIS for the New York City Department of Information Technology and Telecommunications, October 2001, after the September 11 2001 World Trade Centre attack (Greene, 2002). There is no better statement to describe the use of GIS in disaster and risk management. Owing to the effects of the Internet and GIS on personal digital assistants (PDA), disaster and risk management took on new dimensions. The disaster or risk area can be downloaded from the Internet to a PDA and the field worker collects the information and sends it back to the operations centre via the

Internet (Greene, 2002). The same is done in interactive mapping via the Internet, which allows near real-time or real-time assessment of changing disaster conditions. The GEOMAC system of the United States Geological Survey is such an example (Greene, 2002). However, all this can fail owing to a lack of knowledge by the users, either of GIS or the models, and to accessibility problems such as the Internet being off-line (Zerger and Smith, 2003). According to Greene (2002), there are normally five stages in disaster management, namely:

- Identification and planning
- Mitigation
- Preparedness
- Response
- Recovery.

The first three are the stages before a disaster occurs (risk management) and the latter two are the stages once a disaster has occurred. It is also here where the supply chain of the necessary GIS products, the resources (software, hardware and personnel), the suppliers and "customers" is planned, which corresponds to the PLAN process of the SCOR model. The quality of the last two stages depends on the quality of the first three stages. Supply chain management can ensure the quality of the first three stages. The last two stages link to the SOURCE, MAKE, DELIVER and RETURN supply chain processes using the SCOR model approach. The discussion in this section is based on these five stages.

Stage 1: Identification and planning

Disasters or risks can be identified at a local level, such as nuclear power plants, chemical plants (Gheorghe *et al.*, 2000 and Contini *et al.*, 2000), construction sites (Cheng *et al.* 2002) or parts of rivers (Sinnakaudan *et al.*, 2003). Figure 3.17 shows an area that is at risk of flooding along part of a river. Examples of country level are the Canadian spatial fire management system

(SFMS) (Lee *et al.,* 2002) and the South African Advanced Fire Information System (AFIS) developed by the Satellite Applications Centre at Hartebeeshoek near Pretoria, South Africa (Wentzel, 2006). At regional level, the locations of chemical and other hazardous material manufacturing plants are mapped using the Seveso Plants Information Retrieval System of the European Union, or routes along which hazardous material is transported (Gheorghe *et al.*, 2000). Another example is coastal regions that are prone to hurricanes and/or storm surges (Greene, 2002), such as the regions around New Orleans that were hit by Hurricane Katrina on 25 August 2005. By knowing beforehand which areas are at risk, the necessary evacuation plans can be put in place.

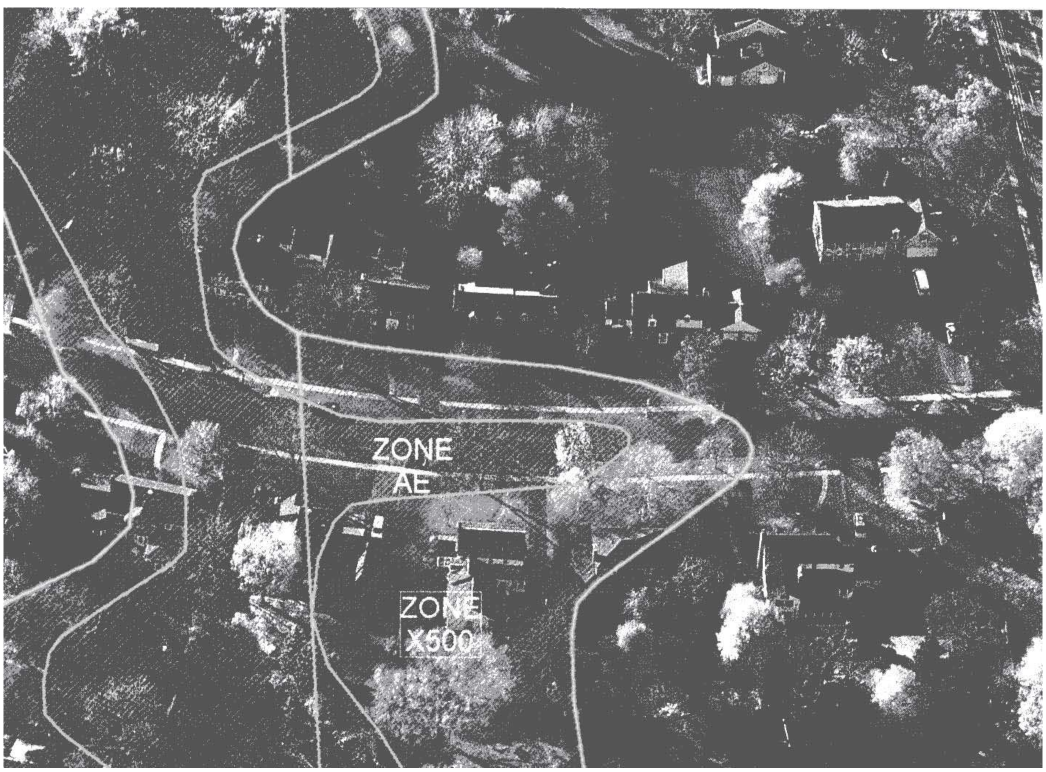

Figure 3.17: Areas at risk of flooding
(from Artés, 2006:23)

Several models have been developed for use with GIS to identify areas that are at risk, such as:

- HAZUS, which models loss-estimations for earthquakes and floods (Greene, 2002).

- ARIPAR-GIS, which deals with area risk analysis and control (both at hazardous sites and in the transportation of hazardous substances). It uses accident scenarios, past incidents, accident frequencies at sites, etc. (Contini *et al.*, 2000)
- ETH-NUKERISK shows expected zones at risk of radio-active contamination and fallout.
- KOVERS decision-support system is used for assessing risks of a route along which hazardous substances are transported. The aim is to identify the route with the lowest accident risk and to optimise emergency preparedness and management (Gheorghe *et al.*, 2000).

Based on the results of the models, the different areas at risk can be identified and the necessary planning can be done, which includes data sharing agreements between different interest groups when the data are needed for reacting to a disaster (Greene, 2002). HARIA-2 is a tool that is used to develop emergency plans for the area surrounding a hazardous site. Once the plans are in place the decision-maker can then, using HARIA-GIS, simulate the accident response based on actions taken, and can compare alternatives to establish the best action for a specific disaster situation (Contini *et al.,* 2000).

Stage 2: Mitigation

Once the areas that are affected by a disaster have been identified, steps can be taken either to eliminate hazards that can cause a disaster, e.g. closure of a plant, or to reduce the effect of a possible disaster. Examples are brush clearing around residential homes and new buildings being built with fire-proof materials. The response time of emergency services can be modelled to determine optimal locations of the services (Greene, 2002), or improved land-use planning can be done around sites where disasters can occur, such as chemical plants (Contini *et al.,* 2000).

Stage 3: Preparedness

This stage consists of emergency plans on how to react to a disaster. From a GIS point of view it considers the following:

- What spatial data are needed to respond to a disaster (simple is better)?
- Where these data and their metadata can be found: is it better to obtain it from the different sources, or to have it stored at a specific location from which it be retrieved? Should there be alternative sources if the original source is destroyed, such as it was the case when the World Trade Centre was attacked (Greene, 2002)?
- What software is available that can assist in emergency planning and/or training, such as HARIA-GIS (Contini *et al*., 2000) and CATS (consequences assessment tool set) (Greene, 2002)?
- In what format should the results be made available? Should maps be printed on paper or should the data be downloaded onto PDAs or laptops, which allow on-site updating of data?

The advantage of using CATS and HARIA-GIS is that one can simulate disaster response based on emergency plans and actions for training and refine the plans and actions (Contini *et al.*, 2000 and Greene, 2002).

To enable timely response to disasters, supply chain management can be used to establish the flow of data when the need arises by identifying the resources needed, planning from where the resources will be sourced and what is already available. This is similar to planning the creation of the relevant GIS products needed as well as the dissemination of the products.

From a supply chain planning point of view using the PLAN process of the SCOR model as mentioned before, this stage is linked to the following process categories of PLAN. The required spatial data are identified in PLAN MAKE (P3), which deals with the creation of the necessary GIS products to enable the disaster response team to react speedily to a disaster and the type of software needed. Part of the PLAN MAKE process is the identification of human resources to create the GIS products. The PLAN SOURCE (P2) process category plans the sources of the required data sets, who the suppliers are, what metadata are available, and alternative sources of the same type of data. PLAN SOURCE plans the feedback of data from the field teams, which can be in real-time or near real-time, to the centre using the Internet via wireless applications. PLAN DELIVER (P4) is used to plan the delivery mechanisms of the GIS products created using the input data and the identified software. Delivery mechanisms can be paper maps or can be in the form of dissemination of the GIS products via the Internet to the field teams in real-time or near real-time. PLAN RETURN (P5) is used to plan the necessary activities when the centre receives faulty data from the suppliers. PLAN (P1) provides the overarching supply chain plan which considers the whole supply chain from the planning stage to sourcing, making, delivery and possible return of the various GIS products.

Stage 4: Response

Once a disaster has occurred, it is responded to using GIS to map the areas of the disaster, such as Ground Zero and surrounding areas in the aftermath of September 11, as well as keeping track of the response deployment. GIS maps are also used to indicate the locations of hospitals, police, etc. and temporary stations and mortuaries (Greene, 2002).

New data and information can be loaded immediately and promptly disseminated to the different response teams via the Internet, CD-Rom or the humble paper map. Paper maps were used by the teams who worked at Ground Zero and surrounding areas during 9/11 (Greene, 2002).

Greene (2002) refers to this kind of GIS work as Combat GIS, due to its fast pace, intense working conditions and the output which is used immediately. The following are part and parcel of a Combat GIS (Greene, 2002):

- Speed: Fast working and thinking under a lot of pressure is important.

- Culture: GIS personnel must understand the culture of disaster response to be able to provide the correct support.
- Hardware and software design: Must be mobile, flexible and be able to be interconnected wherever it is located.
- Directory structure: Pre-designed directory structure for the location of data, some already populated and some not, gives stability and makes data access simple.
- Physical space: Adequate physical space for working and storage is essential.
- Interdependencies and communications: Due to the nature of the applications of Combat GIS, it is necessary to have the contact details of personnel, the different agencies, data providers and vendors of hardware and software.
- Standardised map and data products: Those that is necessary for the job and the degree of simplicity.
- Map templates: A pre-defined map layout with all the necessary symbols is essential to save time.
- Staffing: The right people must do the work and training sessions must be held to prepare for real-life events.
- Media: The media will need maps for news coverage during and after a disaster and also so that the media can inform the public about emergency and evacuation procedures.

As mentioned above, speed is the most characteristic aspect about a "Combat GIS". It can be realised better by using supply chain management. As mentioned in Stage 3, the planning part of the supply chain puts the processes into place that enable speedy production of GIS products needed to respond to a disaster. In this stage the other four process categories of the supply chain come into play, namely SOURCE, MAKE, DELIVER and RETURN. The SOURCE process establishes the manner in which the data will be sourced from the identified preferred and alternative suppliers. Data deliveries by suppliers are established through service-level agreements. The manner of delivery as mentioned above is included in the agreements, such as the format of the data (i.e. raster, vector, ESRI shape file, etc.), metadata content, data quality, scale of spatial data (1:1 000 or 1:5 000, etc.), and the medium of delivery (CD-ROM, DVD or Internet download from an FTP site, etc.) The SOURCE process also directs the directory set-up for the data warehouse which will store the sourced data sets to enable ease of data retrieval by the GIS. An advantage of using supply chain management is that a standardised sequence of activities for data sourcing is established, namely: scheduling of the delivery of the required spatial and non-spatial data from the identified suppliers, the process involved in receiving the data in the pre-arranged formats, verification of the received spatial and non-spatial data, and the placing of the received spatial and non-spatial data at the correct locations in the data warehouse (Supply-Chain Council, 2001 and Schmitz, 2006).

The MAKE process of the supply chain deals with the scheduling and the actual creation of the required GIS products, which includes the type of software and hardware, and infrastructure and personnel. MAKE regulates the standardisation of map and data products and the different GIS processes, e.g. the creation of buffers at a specified distance around a hazardous spill and the querying of spatial data such as the number of people in danger of contamination, the routes to evacuate the identified people from the danger zone, etc. Quality control and regulatory adherence of the GIS product are part of the MAKE process. The GIS product is delivered in the required format such as a digital format for downloading on a PDA, or as a paper map for delivery to the people who have to manage and make decisions on responses needed to minimise the impact of the disaster (Supply-Chain Council, 2001 and Schmitz, 2006). The “Combat GIS” unit’s SCOR Level 2 MAKE process is the Make-to-Stock process category, which includes rapid updates with the aim of having as many GIS products to hand as required that can be delivered as quickly as possible.

DELIVER is concerned with methods of how quickly the GIS products can be delivered to fulfil customer orders. Depending on the data format, the unit must be able to download data from their server to PDAs using USB links, or they must be connected to the Internet to download the data or have high-speed plotters to print paper maps on request.

Owing to the function of this unit, the RETURN processes are limited to the return of faulty data which the unit cannot rectify or if the data medium such as a CD-ROM, DVD or removable hard disk is faulty.

Supply chain management allows the creation of performance metrics for measuring the performance of the supply chain, such as time spent on sourcing the data from suppliers from ordering to the physical receipt of the data. Performance metrics can also deal with data quality issues during the sourcing process. Performance metrics can be used in the manufacture of the GIS product: the time spent creating the GIS product (from the release of the required spatial and non-spatial data from the data warehouse to placing the completed GIS product in the data warehouse or the printing of a paper map showing the results); the capacity utilisation of the hardware and GIS software in the creation of the GIS product to establish whether the resources are being used at maximum capacity or not; and the time lost due to faulty data or lack of the required skills needed to create the GIS product. The performance metric information is collected after completion of the disaster response and the results are used during the debriefing session to improve the performance of the "Combat GIS" unit when the next disaster occurs.

Stage 5: Recovery

Once the emergency response to a disaster has been completed, the recovery period begins and life starts to return to normal. GIS also plays an important part during this phase. Greene (2002:72) gives the example of ShakeMaps, which are maps showing areas of damage after an earthquake using ZIP codes as the mapable unit. The severity of the damage is based on the Mercalli scale which gives an indication on how much money must be allocated for assistance in these areas. It also assists with determining the locations of assistance service centres, keeping the people informed and managing the clean-up processes (Greene, 2002). During the recovery phase supply chain management can be applied in a similar manner as discussed in Stage 4. Depending on the scale of the disaster the "Combat GIS" unit may have to rely on core data sets such as cadastre to enable them to contact people about evacuation from an area. The next section discusses the creation and maintenance of core data sets.

3.5.2.2 Creation and maintenance of core spatial data sets

Each country has its core spatial data sets that are held in the custodianship of a government department or outsourced companies. This section will examines some examples of core spatial data sets in South Africa. The newly proclaimed Spatial Data Infrastructure Act of 2003 governs core data sets.

The first example is the core data sets that are produced by the Chief Directorate: Surveys and Mapping (CD:S&M). CD:S&M, according to their Website, are responsible *for the official, definitive, national topographic mapping and control network system of South Africa* (CD:S&M, 2006a). They provide the following products and services:

- Maps
- Aerial photography
- Survey services
- Computer data.

CD:S&M's clients are typically government departments, private institutions, planning departments and organisations, educational institutions (schools and tertiary institutions) as well as the leisure sector (CD:S&M, 2006a). For the purpose of this research, the map product range is discussed since maps are the most commonly used products. CD:S&M provides the following maps in paper or digital format (CD:S&M, 2006c):

- Topographical maps (see Figure 3.18), also available in digital format
- Topo-cadastral maps
- Topo-administrative maps also available in digital format
- Provincial maps
- Aeronautical maps.

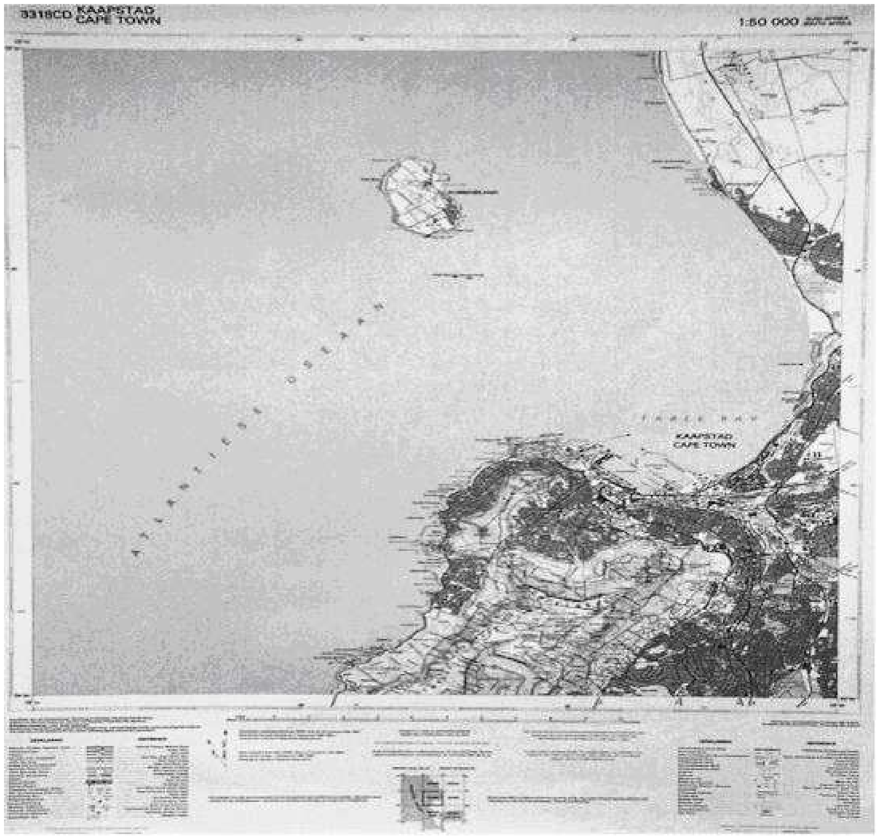

Figure 3.18: Example of a 1:50 000 topographical map

(downloaded from http://w3sli.wcape.gov.za/IMAGES/Topomap.jpg on 14 May 2006)

Other digital data provided by CD:S&M for use in a GIS are digital elevation models (DEM) at 400 m x 400 m, 200 m x 200 m and for selected areas at 50 m x 50 m resolution. All the maps listed above are available as scanned images, which can be used as backdrops for maps. Finally, a digital product made available by CD:S&M is the digital orthophoto series. These orthophotos are georectified aerial photographs and are provided in geo-tiff (.TIF/.TIFF) format (CD:S&M, 2006c).

The second examples of core spatial data sets are those from the Municipal Demarcation Board (MDB). The MDB was established as an independent authority responsible for creating and maintaining municipal and related boundaries in terms of Section 155(3) (b) of the Constitution (Act 108 of 1996), Section s3 and s4 of the Local Government: Municipal Demarcation Act, 1998

(Act 27 of 1998) and the Local Government: Municipal Structures Act, 1998 (Act 117 of 1998) (MDB, 2006a). The following spatial data sets are available form the Municipal Demarcation Board (MDB, 2006b):

- Municipal boundaries
- District municipal boundaries
- Ward boundaries
- SA Explorer.

SA Explorer Version 3 consists of the following spatial data sets (SA Explorer, 2005):

- Parent farm boundaries
- Place names as per Census 2001
- Schools as in 2000
- Voting stations as in 2000
- Transmission lines and substations as in 2001
- Health facilities as in 2003
- Dams, rivers and DWAF water projects and schemes
- Courts and Magisterial Districts
- Prisons
- Old (disestablished) district councils and transitional local councils
- Towns
- Traditional areas
- Municipalities
- Public Works projects (1998 – 2001)
- Airports, railways, and national, main and other roads.

There are other spatial data sets such as the National Address Dictionaries from AfriGIS and The Knowledge Factory. The Knowledge Factory has spatial data sets available on market segmentation, demographics and income, market research, property and cadastral data (The Knowledge Factory, 2006).

The creation of these core data sets by the supply chain and supply chain management follows a similar format as discussed in Section 3.5.2.1. PLAN processes are geared in this instance to create these core data sets over a much longer time period than those created by a "Combat GIS" unit. The maintenance of the core data sets as required by law are incorporated within the PLAN processes as a specific MAKE function, whereas in the "Combat GIS" situation the maintenance of the data is part of the normal data creation process (Make-to-Stock).

To enable the SCOR model to model the large-scale scheduled maintenance of core data sets, a fourth SCOR Level 2 MAKE process has been added for the purpose of this study, namely Maintain-to-Stock, in addition to the existing three SCOR Level 2 processes of Make-to-Stock, Make-to-Order and Engineer-to-Order (Schmitz, 2006). When a core dataset is created for the first time, the SCOR Level 2 MAKE process category is Make-to-Stock. Once the core dataset has been created it will be updated (maintained) at regular intervals to keep the dataset current. This regular maintenance of the core dataset is managed using the Maintain-to-Stock process category of the MAKE process of the supply chain.

Owing to the nature of core data sets, the DELIVER process of the supply chain using the SCOR Level 2 process categories is Deliver Stocked Product, where the unit responsible keeps the core dataset in a data warehouse or server from which the relevant core dataset is extracted when an order is placed by a client. Several delivery modes are available, such as CD-ROM and Internet sites from which these core data sets can be downloaded. An example of the latter is the AGIS (agriculture GIS) Website run by the Department of Agriculture. ArcIMS is used on one of the Web pages so that the various data sets can be quickly selected over the Internet. Once the user has decided on the relevant data sets, he or she goes to another Web page on the Web site to download the required data which is in stock (Lindeman, 2006). The URL of the Web site is http://www.agis.agric.za/agisweb/nr_atlas.

The RETURN processes in the supply deal with faulty data received from the GIS unit's suppliers, such as missing metadata and data that do not meet the set requirements for the different standards applicable to the data sets which have been ordered. The other side of the RETURN coin is the different processes that the GIS unit creates. These core data sets must rectify faulty data that the unit has delivered to its customers.

This section and Section 3.5.2.1 discuss two examples of the application of a GIS, namely responding to disasters and the creation and maintenance of core data sets. The next section gives a few other examples where GIS is used to create specific GIS products.

3.5.2.3 Examples of other GIS applications

The use of maps to map crime started in the 1830s in France. Then the focus was on the distribution of wealth and population densities and their relationship to crime levels (Harries, 1999). According to Harries (1999), there were three schools of thought in the study of the spatial distributions of crime:

- The cartographic school, which started in France as mentioned above.
- The typological school, which concentrated on "the relationships between the mental and the physical characteristics of people and crime (Harries, 1999:4)".
- The social ecology school, which looked at the "geographic variations in social conditions under the assumption that they were related to patterns of crime (Harries, 1999:4)". GIS plays a very important role in this school because of its capability to handle multiple layers of geographically related data, such as demographics, economic data, land cover, land and as locations of crime incidents.

Computerised mapping was already being done in the mid-1960s in St Louis. Other soon followed. Since the early days of computer mapping, thematic mapping was also used to map areas for trends and incidents. In the early days crime mapping was done mostly for research purposes (Harries, 1999). Crime mapping as part of a police station's every-day business started in the 1990s with the inception of sophisticated software and powerful desktop computers (Harries, 1999).

There are several ways of mapping crime. Crime can be mapped as a point (virtual pin-map), as line data, such as connecting places where vehicles were stolen to where they were recovered, and discrete distributions, such as crime per square kilometre for each suburb or as a continuous distribution, which shows areas of high and low incidents of crime similar to topographic maps (Harries, 1999).

Tactical crime mapping is used in South Africa to assist the police during investigations such as linking crime scenes to scenes indicated by a suspect and searching for dockets based on scenes indicated (scenes are mapped and by overlaying police station boundaries the dockets can be requested from the appropriate police station). Tactical crime mapping is also used for prosecution purposes (see Figure 3.19).

Figure 3.19 shows a map that was used to prosecute two hijackers who hijacked and took hostage a couple in the early hours of 5 January 1998. There were initially four hijackers, but two died during a shootout with the police. The map shows the communication between the suspects. It also shows locations of interest to the case such as the murder and rape scenes and the house of a witness where the gang met after the rape and murders (Cooper and Schmitz, 2003).

Crime maps are used to visualise crime incidents, but most importantly, they assist in crime analysis and display the results of the analysis. Maps indicate possible correlations between crime incidents and the environment; they can show possible trends and patterns of criminal activities. These can in turn be used to predict future patterns, thus enabling preventative measures to be put in place. Maps can also be used to analyse interventions, i.e. where the criminals move to because of proactive anti-crime activities by the police.

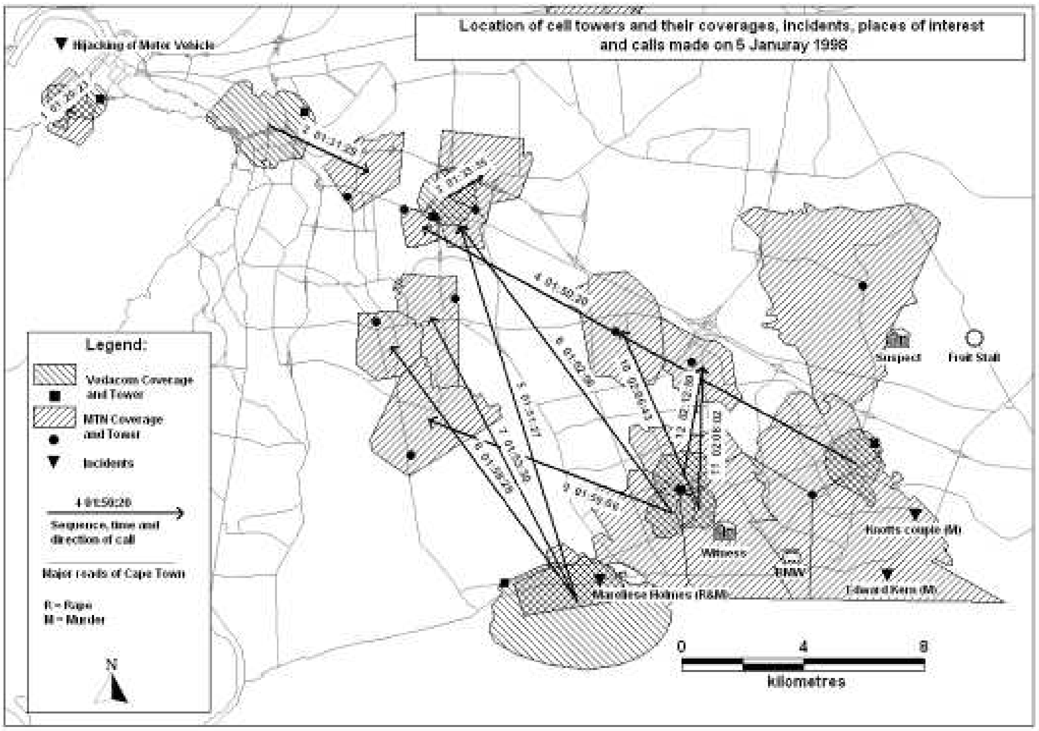

Figure 3.19: Crime map used to prosecute suspects by using cellular telephone and other related information

(from Cooper and Schmitz, 2003, Figure 2)

Another example of the use of GIS is the creation of land information data sets . Land information dates back to 4 000 BC in Egypt (Dale, 1991), and an example from Babylonia shows the boundaries of a land parcel plus the information linked to it dating back to the third dynasty of Ur (1 000 BC). Land information is also used for taxation. Another well-known example of linking land parcels to owners' information is the *Doomsday Book* of 1085-86 in England (Moyer and Niemann, 1998).

Nowadays, land information systems (LIS) are sometimes known as multi-purpose cadastre (MPC) or multi-purpose LIS (MPLIS). For this doctoral research, LIS encompasses all of the above, and includes the following:

- A geodetic reference framework such as the South African LO system
- Base maps (large-scale topographic maps)
- Cadastre (parcel definition)

- Linkage mechanisms (such as using a unique ID, e.g. the 21-number code of the Surveyor General in South Africa).
- The following are then linked to the cadastre:
    - Land tenure data
    - Land value data
    - Land use
    - Administrative data
    - Natural resources
    - Utilities and infrastructure
    - Buildings and other construction data
    - Administrative data
    - Population and census data (Dale, 1991:87 and Moyer and Niemann, 1998:95).

To have an effective LIS, each participating department, agency or enterprise has to be responsible for the capture, storage and maintenance of its domain-specific data sets. For an LIS to be effective, each participant must base its spatial dataset on the same geodetic reference framework (Moyer and Niemann, 1998). The participating parties must negotiate as to which party will be responsible for setting and maintaining the standards of the LIS. They must also negotiate on how, when and what data will be shared (Dale, 1991).

LIS can be used to manage soil erosion in rural areas and to identify which owner is not complying with the regulations, and he can be fined for non-compliance (Moyer and Niemann, 1998). Other applications range from accessing land parcel information on-line (e.g. Australia) (Dale, 1991) to complex town planning and management (Moyer and Niemann, 1998).

The last example of the use of GIS is where the GIS is used for various business analyses, such as where to place new products in the market, finding the optimal location of a new office, etc. Grimshaw, 1993, as referenced in Toppen and Wapenaar (1994), classified GIS applications in the business sector into three classes, namely:

- Strategic
- Tactical
- Operational.

The strategic level is the high-level information used to determine where to invest or where to place which new products (Toppen and Wapenaar, 1994). GIS maps showing the regional market share of Lada and BMW motor vehicles in the UK (Birkin *et al.*, 1999) are examples of this. Using finer geographical detail (several postal code areas within a region), the market penetration of several retail outlets belonging to the same motor vehicle make can be mapped, which can show the decline in penetration related to the distance from the outlets (Birkin *et al*., 1999). Based on the information presented, different strategies can be formulated, which in turn guides the tactical analysis.

Tactical applications are, for example, assessing market potential, determining the revenue of the store(s) and determining the location of a new outlet. One modelling method used in GIS to determine the above is known as spatial interactive modelling to determine the catchment areas to calculate store revenue (Birkin *et al.*, 1999). Birkin *et al.* (1999) argue that spatial allocation models can be extended to analyse resultant flow patterns of consumers from different regions to different stores, which can then be further exploited to determine the performance indicators for the residents (consumers) or the facilities, which can lead to the location of a new outlet. Another spin-off according to Birkin *et al.* (1999) is the construction of regional "typologies", which can be used for target marketing (Mariahazy, 2002) to assist in the location of a new store or management of the enterprise based on the performance indicators.

The last application is operational planning, such as determining the shortest route to deliver products or services. Deliveries can be made from the various factories to a warehouse or from the warehouse to the different retail outlets (Toppen and Wapenaar, 1994 and Mariahazy, 2002) or from retail outlets to homes. An example of the latter is the home delivery service of Pick 'n' Pay.

Another type of operational planning is the use of GIS to assist in the warehouse site selection for the optimal and least cost of delivery of goods to customers or outlets, using linear multi-criteria evaluation models to determine the best location (Vlachopoulou *et al.*, 2001).

Flowmap can be used to place new service locations (expansion models) such as offices for the Department of Home Affairs (see Figure 3.20 and Table 3.2) to enable the department to service a high percentage of its customer base within 30 minutes of travel from any office (Schmitz *et al.*, 2005). For business purposes Flowmap has a routine that will place a facility in such a location that it will optimally catch the competition's customer base (De Jong, 2006). The next section looks at GIS and environmental applications.

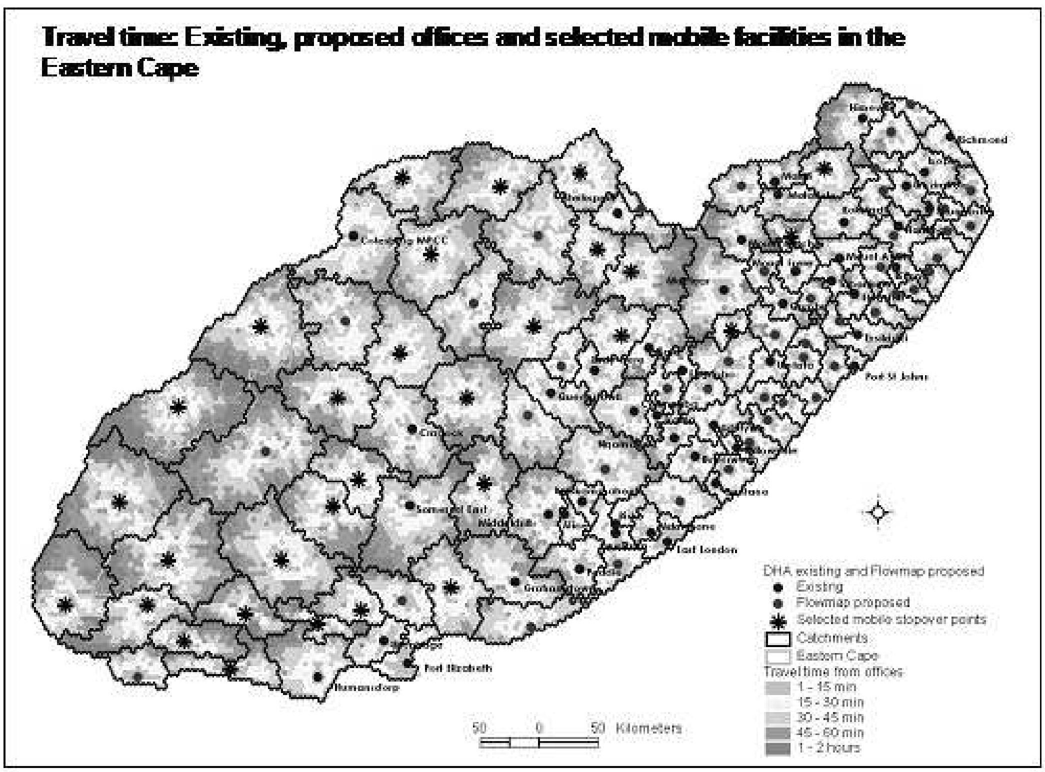

Figure 3.20: Location of proposed new offices for the Dept. of Home Affairs
(from Schmitz *et al.*, 2005)

Table 3.2: Percentage of the Eastern Cape population served by existing and proposed offices and selected mobile stopping points

Travel time category	Existing facilities (47)		Existing (47) and proposed permanent service points (45) [n = 92]		Existing (47), proposed permanent (45) and selected mobile stop points (30) [n = 122]	
	%	Population	%	Population	%	Population
Up to 15 min	29.0	2 227 367	37.5	2 875 530	38.5	2 955 242
Up to 30 min	54.0	4 142 605	79.2	6 079 206	82.3	6.305 357
Up to 45 min	73.3	5 625 422	92.3	7 080 076	96.0	7 363 809
Up to 60 min	84.5	6 481 635	96.7	7 418 556	99.1	7 595 541
Up to 75 min	91.4	7 007 653	98.0	7 519 523	99.7	7 648 161
Up to 90 min	95.4	7 320 390	98.8	7 579 022	99.9	7 663 408
> 90 min	4.6	345 829	1.2	87 197	0.1	2811
Ave. travel time	35.1	--	22.3	--	17.2	--
Worst Case	289.0	--	199.0	--	199.0	--

(from Schmitz *et al.*, 2005)

This section gave a few examples of the application of GIS and how supply chain management can be used to assist the GIS unit to create specific GIS products using the different supply chain processes using the SCOR model.

3.6 Conclusions

Geographic Information Systems have developed over the years into very sophisticated systems which must be properly implemented in an organisation, are subject to legal requirements and standards that must be adhered to, and which have a wide range of applications as demonstrated in Section 3.5.

The definition of a GIS clearly indicates a supply chain. To acquire data (spatial and non-spatial), it must be sourced from a single source or various sources. The storage, retrieval, transformation and manipulation of the data are done at the GIS unit. The data are displayed either at the GIS unit itself, or the GIS product, which consists of transformed and manipulated data, is displayed at the GIS unit's customer/s.

Linking the above to the main aspects discussed in Chapter 2, the acquisition of data can be linked to logistics management (Section 2.4.2), especially order processing, inventory (the different data sets used by the GIS) and transportation of the acquired data to the GIS unit. Warehousing can be seen as data warehousing in the context of GIS. The data as well as the various software and hardware that are used by the GIS unit can be grouped as materials in the context of supply chains. The material that needs to be procured (links to order processing) (Section 2.4.3.1) is determined by the production plan (Section 2.4.3.3). Receiving (Section 2.4.3.5) deals with the various activities that the GIS unit needs to carry out when the unit receives the required data. Warehousing deals with the storage and retrieval of the data.

Operations as discussed in Section 2.4.4 can be applied to the transformation and manipulation of the data by the GIS unit. Through forecasting (Section 2.4.4.2), the GIS unit can determine the various GIS products that it needs to create and what materials it needs to create these products. Operations planning (Section 2.4.4.3) can, in the context of GIS, consist of materials requirements as well as the various transformation and manipulation processes the unit needs to follow in order to create the GIS products. As discussed in Chapter 2, adherence to legal requirements and standards is part of supply chain management since it improves the quality of the product being manufactured (see Section 2.4.4.4). If the GIS unit is a business, it needs to market its services and GIS products. The marketing aspect of the supply chain is discussed in Section 2.4.5. Through marketing the customer receives the required GIS product and can thus display the GIS product for further use. With regard to global supply chains, an example in the context of GIS is the acquisition of satellite imagery from satellite operators who are mostly located in a different country than the GIS unit.

In Section 3.5 it was demonstrated briefly that supply chains and supply chain management can be used to manage the flow of spatial and non-spatial data from the suppliers to the GIS unit, the GIS product creation by the GIS unit and the delivery of the product to a customer. The definition of a GIS as given in Section 3.3 also clearly indicates that GIS by nature contains the characteristics of a supply chain. It can thus be concluded from the above discussions that since

GIS implicitly has the characteristics of a supply chain, and it partly answers the research question, namely that supply chains can be established in the context of GIS. It can therefore be assumed that the management of this supply chain could be done through supply chain management. Within the context of remarks by GIS specialists, such as Dangermond (1999) and Tomlinson (2000), we now find ourselves in a position where much bigger emphasis must be placed on GIS management. The next objective is to determine to what extent GIS is currently managed and how.

Chapter 4: Management of Geographic Information Systems

4.1 Introduction

To answer the question for objective C, namely “**How is GIS currently managed in GIS units?”** it is necessary to investigate current GIS management practices. In an effort to provide an answer, this chapter starts with an overview of GIS management based on the types of GIS implemented in an organisation as well as the fundamentals of GIS management.

From the overview, three types of GIS management were identified. The first is the management of implementing a GIS in an organisation. As part of this, the implementation process, which is touched on in Chapter 3, is dealt with in detail to lay the basis for discussing the implementation management of a GIS. The second type of management is the management of an operational GIS. The third type is maintenance management which deals with the maintenance of hardware, such as printers and plotters, software that needs to be upgraded when the supplier releases a new version, and the spatial data and its related attribute data sets.

Workflow is discussed as a management tool to automate certain aspects of the GIS product manufacturing process to improve the efficiency and quality of manufacturing. The management of special GIS projects, which are once-off projects such as the change of a geographic datum (i.e. from Clarke 1880 to WGS84), using standard project management methods is also discussed. The last section of this chapter deals with some reasons why the implementation of a GIS in an organisation can fail, such as the lack of understanding of the scope of the GIS, inefficient management of the GIS itself, and the failure of the implemented GIS. Data and database management are discussed as part of the implementation, operation and maintenance management of GIS.

4.2 Overview of GIS management

Public and private organisations implement a GIS to satisfy a specific need or to achieve the organisation's strategies and goals. The need, strategy or goal determines the type of GIS (Somers, 1998 and Sugarbaker, 1999). Sugarbaker (1999) mentions three types of GIS that can be implemented, namely:

- An enterprise or corporate GIS which spans the whole organisation and is used by several departments to support the organisation's mission-critical functions. It is placed within and managed by the information technology support function of the organisation. One of the main aims of an enterprise GIS is the reduction of duplications, whether data sets or operations (Somers, 1998 and Sugarbaker, 1999).
- A departmental GIS is used by a designated department in an organisation to support the organisation's strategies and goals. The designated department manages the departmental GIS, but the information technology (IT) infrastructure that is utilised by the department is managed by the IT function of the organisation (Somers, 1998 and Sugarbaker, 1999). Somers (1998) refers to a departmental GIS as a data and service resource that provides data and services to other departments when the need arises, or as a GIS that is used as a business tool to assist in the decision-making for marketing and customer relationships using mostly demographic and economic data.
- A GIS project which has a specific life span. The end result is a GIS product used by the organisation. The management style used during the GIS project is based on standard project management principles. When the project is completed the GIS is terminated and the staff are placed somewhere else within the organisation (Somers, 1998 and Sugarbaker, 1999).

To enable the successful management of a GIS, either during the implementation, operations or maintenance stages, it must be based on fundamentals. The maintenance of a GIS includes the expansion of the GIS to satisfy the growing needs of the organisation. The fundamentals of GIS management, not necessarily in this order, are:

- GIS demand pull, i.e. there the organisation needs to use GIS to achieve its goals and objectives. The GIS implementation must be linked with the business plan of the organisation (Obermeyer and Pinto, 1994; Huxhold and Levinsohn, 1995; Reeve, 1998; Somers, 1998 and Harrison, 2004a).
- Proper change management is needed to manage the impact of the GIS on the organisation and its staff, and includes communication and skills development (Huxhold and Levinsohn, 1995; Harrison, 2004a and Moy, 2004).
- Although the principles of GIS have been discussed in detail in Chapter 3, it is necessary to present them in a summarised form as defined by the International Association of Assessing Officials and listed in Huxhold and Levinsohn (1995:32) to place it within the context of the management of GIS. Obermeyer and Pinto (1994), Birks *et al.* (2003), Harrison (2004a) and Moy (2004) share these principles which are seen as critical to ensure the successful implementation and use of a GIS. The nine principles are:

    1. *A GIS is a data-driven, data-based information system.*
    2. *GIS data and maps must be maintained.*
    3. *A GIS is most useful when geographic references are registered on a consistent, continuous coordinate system.*
    4. *A GIS has topology.*
    5. *A GIS has many uses and should be shared by many different functions.*
    6. *A GIS contains hardware and software that are constantly undergoing change, which improves its functionality over time.*
    7. *A GIS grows incrementally in terms of technology, cost and administrative support needed. Therefore a long-term commitment is needed to assure success.*
    8. *A GIS causes changes in procedures, operations and institutional arrangements among all users.*

9. *A cadre of trained, educated, motivated and dedicated people is crucial for a successful GIS programme.*

- A clear vision that is shared and understood by everybody within the organisation (Huxhold and Levinsohn, 1995; Birks *et al.*, 2003 and Harrison, 2004a).
- A formal and clearly defined plan regarding the determination of the user's needs; determination and acquisition of the right technological systems, which includes GIS; the data needed for the GIS and the management thereof; and the structure, phases, funding and monitoring of the GIS implementation (Huxhold and Levinsohn, 1995; Reeve, 1998; Somers, 1998; Birks *et al.*, 2003; Harrison, 2004a and Moy, 2004).
- Spatial data and the related attribute data are a strategic asset (Huxhold and Levinsohn, 1995).
- The current information technology infrastructure of the organisation must be understood to determine whether it can support the implementation of a GIS (Huxhold and Levinsohn, 1995).
- The soft issues regarding the implementation of a GIS must be understood. These are the organisational culture, the dynamics of people operating in teams, and the impact of change on staff and organisational culture (Obermeyer and Pinto, 1994; Huxhold and Levinsohn, 1995; Reeve, 1998; Somers, 1998 and Harrison, 2004a).
- Buy-in and commitment by senior management and staff (Huxhold and Levinsohn, 1995; Birks *et al.*, 2003; Harrison, 2004a and Moy, 2004).
- The goals and objectives of the implementation of a GIS must be clear, but should at the same time allow adjustments during implementation (Huxhold and Levinsohn, 1995 and Birks *et al.*, 2003).

This section discussed the three types of organisational GIS that can be implemented and the fundamentals upon which successful GIS management is based. The next investigates the different types of management, namely implementation, operations and maintenance management that is according to the literature currently used to manage GIS.

4.3 Three types of management: implementation, operations and maintenance

4.3.1 Introduction

This section explores these three different management types, namely implementation, operations and maintenance to gain an understanding of current management practices and to establish to what extent supply chain management is currently employed by GIS units to manage their GIS product production. The management of GIS during its implementation is discussed next.

4.3.2 Implementation management

An overview of the implementation of a GIS into an organisation is given in Chapter 3, Section 3.4.5.1. In this section the implementation of a GIS is discussed in more detail.

When a GIS is implemented in an organisation, ten aspects must be managed during this phase. The first aspect is the establishment of the implementation team. The next seven aspects are: planning the GIS; user requirement analysis; the design of the GIS; system acquisition of the GIS; implementation of the GIS; training; and the legal issues surrounding spatial data. The last two aspects are the resources and the long-term viability of the GIS. Each management aspect is discussed in detail in the following sections (Somers, 1998; Korte, 2001; Bernhardsen, 2002 and Harrison, 2004a) to provide a background on how to manage the implementation which is discussed in the last section.

4.3.2.1 Implementation of a GIS

The implementation process of a GIS into an organisation for the purpose of this study is done in eight stages. The first stage is the establishment of the implementation team followed by: the planning of the GIS; user requirement analysis; cost-benefit analysis; design of the GIS; system acquisition and development of the GIS, the implementation of the GIS; and the training of the

GIS users. Each stage is discussed in detail in the sections below (Somers, 1998; Korte, 2001; Bernhardsen, 2002 and Harrison, 2004a).

4.3.2.1.1 Implementation team

Before a GIS or any other far-reaching process or system can be implemented in an organisation it needs the organisation's support. In the literature reviewed, no unambiguous indication is given of a team which can ensure the successful implementation of a GIS, with the exception of Huxhold and Levinsohn (1995) who only discuss the different role-players during the implementation phase, whereas Bolstorff and Rosenbaum (2003) discuss the role-players from the beginning of the project, i.e. from the point where project need is identified.

In Bolstorff and Rosenbaum's context this is the improvement of the firm's supply chain, which they call the building of organisational support. They discuss the building of support in the context of improving of a supply chain, and suggest that the same principle can be used in building the organisation's support for a GIS and implementing a successful GIS in an organisation. Bolstorff and Rosenbaum (2003) indicate three important role players namely the "evangelist", which Huxhold and Levinsohn (1995) call the GIS champion, the executive sponsor and the core team. For the purpose of this study, the term GIS champion will be used to describe Bolstorff and Rosenbaum's "evangelist".

The GIS champion, according Bolstorff and Rosenbaum (2003), is a person who can run with the idea, can influence executive (*executive* for the purpose of this study is a collective term for the executive officers of an organisation), has a good understanding of the capabilities of a GIS, and has good project management skills. Another characteristic of a GIS champion is good rapport with the rest of the organisation.

Kjörneberg (2002) calls the GIS champion the corporate champion. Obermeyer and Pinto (1994) state that one of the critical success factors of implementing a GIS is the support from top management (executive and management). The executive sponsor according, to Bolstorff and Rosenbaum (2003), is a person who represents the executive of the organisation and who can allocate resources needed for the successful implementation of a GIS. The executive sponsor is the person who sells the concept to executive and the managers, who handles and eliminates any barriers to the implementation of GIS, takes ownership of the financial opportunities and benefits, prepares the organisation for the GIS implementation and ensures the continuous support of executive and managers (Bolstorff and Rosenbaum, 2003).

The GIS champion and the executive sponsor then set up the core team and the members are selected, based on the following capabilities (Reeve, 1998 and Bolstorff and Rosenbaum, 2003):

- High collective experience with regard to their level of authority, have built cross-functional relationships and contributed knowledge to existing processes and how the organisation reacts when a change is introduced.
- The right attitude, such as not having the “not invented here” syndrome. Must have a controlled and adaptive style of communication, and finally must be willing to be effective learners (i.e. be able to adapt and learn the new technology, namely the GIS, fast).
- Must have effective communication skills;
- Must have the ability to cope well with chaos since the implementation of a GIS will bring the organisation to the brink of chaos. The core team must have the ability to sense when things are getting dangerously close to the edge, which can result in a failure to implement the GIS if the situation is not taken care of immediately.

Comparing the above specifications with the implementation team members from Buffalo City it becomes clear that they have created two committees, namely a GIS user committee which investigated the GIS needs of the different users in Buffalo City and a GIS implementation committee which managed the implementation process (Kjörneberg, 2002). Both committees had managerial problems due to the lack of a corporate sponsor, which in this instance would have been senior management and the council of Buffalo City. This was corrected by appointing a "GIS corporate sponsor" from executive management. The Director: Corporate Services of Buffalo City was appointed as the corporate sponsor, which is similar to the executive sponsor in the Bolstorff and Rosenbaum model (Farrant, 2006). The implementation team described above had the responsibility of implementing the GIS starting with the planning. Buffalo City, apart from the implementation team, also appointed a steering committee to oversee and manage the implementation process. The steering committee's functions were to monitor the implementation process, make decisions regarding the project management and changes in scope and to give guidance to the implementation team when the implementation was getting behind schedule (Farrant, 2006).

If a steering committee is appointed, the GIS champion and the executive sponsor must be members of the committee. The first task of the implementation team is to plan the GIS that will be implemented in the organisation.

4.3.2.1.2 Planning of the GIS

One of the GIS planning tasks is to decide where to place the GIS in the organisation. The GIS can either be controlled or managed centrally or it can be decentralised as a line organisation or a support area, or at executive level (Huxhold and Levinsohn, 1995 and Somers, 1998).

Buffalo City decided to control and manage their GIS centrally, and it is even recommended in their phase two implementation report that the GIS should be placed at City Manager's level to give it more legitimacy within the municipality. This would also allow it to link directly with the Integrated Development Plan (IDP) of the municipality (Kjörneberg and Farrant, 2004), i.e. at Somers' (1998) executive level. Somers (1998) states that an organisation that wishes to implement a GIS first needs to determine the scope of the GIS. Obermeyer and Pinto (1994) maintain that the scope is a set of clearly defined goals linked to the strategy and mission of the organisation.

The determination of the scope or goals of a GIS is one of the first tasks to be done by the implementation team and communicated to the organisation by the GIS champion and the executive sponsor for feedback and comments. Based on the latter, the final scope or goals of the GIS are determined and communicated. This forms the basis of the planning of the GIS, which include aspects such as software, staffing, training, data, database development, data maintenance and implementation phases (Obermeyer and Pinto, 1994; Huxhold and Levinsohn, 1995 and Korte, 2001).

The next activity of the implementation team is to collect the background information on why a GIS should be implemented in the organisation based on the scope (Somers, 1998). The information is used by the implementation team to develop a preliminary implementation plan which is communicated to the organisation (Somers, 1998). The preliminary implementation plan can include a user requirement analysis, cost-benefit analysis, design of the GIS, etc. and feedback sessions on each of the planned steps. If an organisation wants to implement a GIS successfully, it must understand the needs of the users of the GIS, including the end user who wants the see the final maps to the high-end user of GIS. The methodology to establish these needs is the user requirement analysis.

4.3.2.1.3 User requirements analysis

A user requirement analysis, according to Huxhold and Levinsohn (1995:87), is the assessment of "*the needs of the organisation, determining the workings of various business units, their information needs and an assessment of how GIS could be applied to the identified work*." This can be done through interviews, questionnaires, observation of current work processes and the analysis of information and data flows within the organisation (Reeve, 1998). A user requirements analysis is also known as a *User Needs Study* (UNS) (Reeve, 1998) and is conducted by the implementation team and managed by the GIS champion, as discussed in Section 4.3.2.1.1.

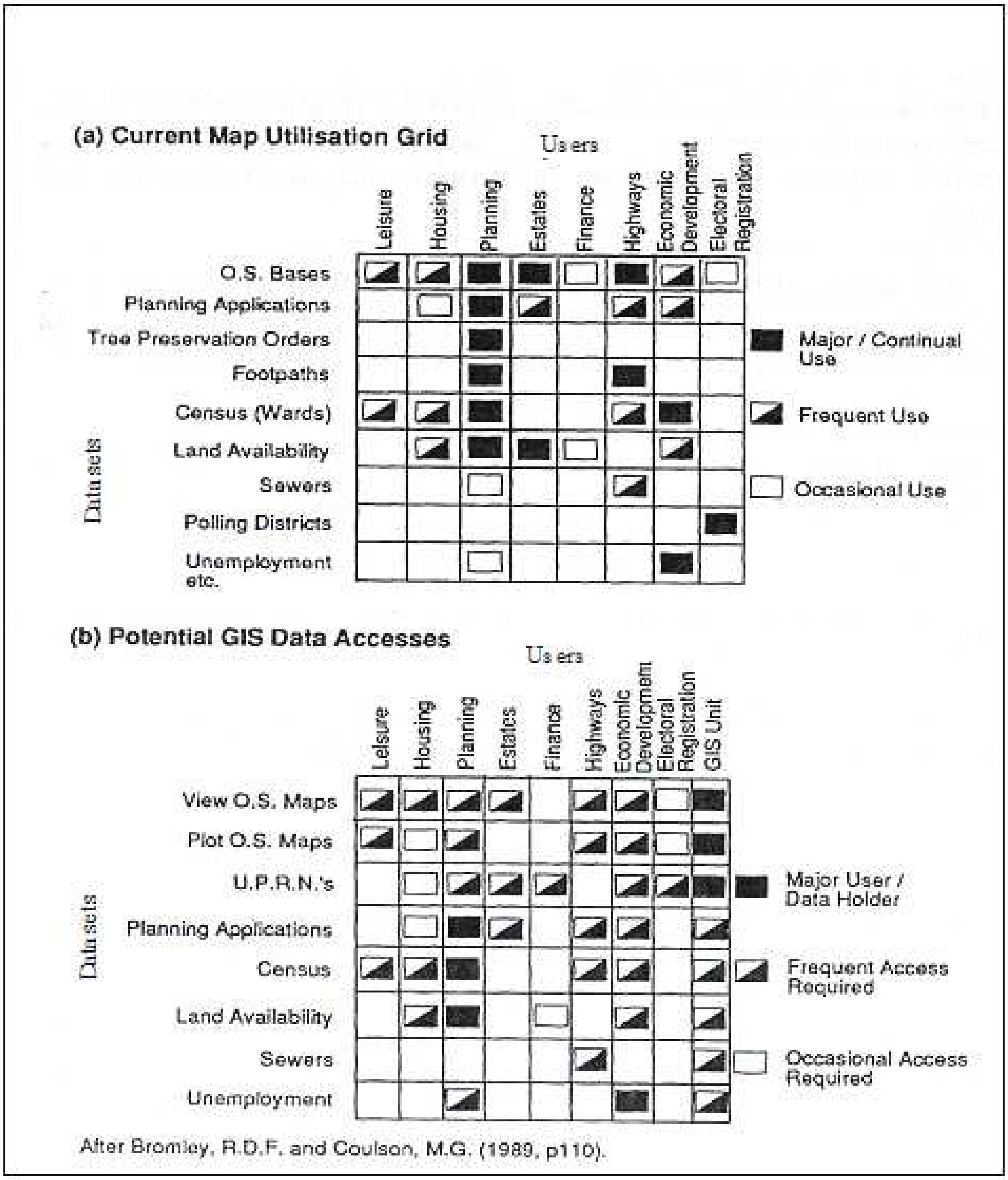

Figure 4.1: Grid charts

(from Reeve, 1998:94, Figure 17)

Reeve (1998) mentions two approaches in conducting a user needs study. The first is the informal method of doing a preliminary estimation of the use of a GIS, with the aim of following it up with a more formal approach. The second approach is a formal user needs study, where every aspect is recorded for future reference, such as the design of the GIS and data design. Apart from conducting formal interviews using questionnaires and analysing them, graphic representations can be used to assist in explaining the user requirements in a report such as grid and flow charts (Reeve, 1998) illustrated in Figures 4.1 and 4.2).

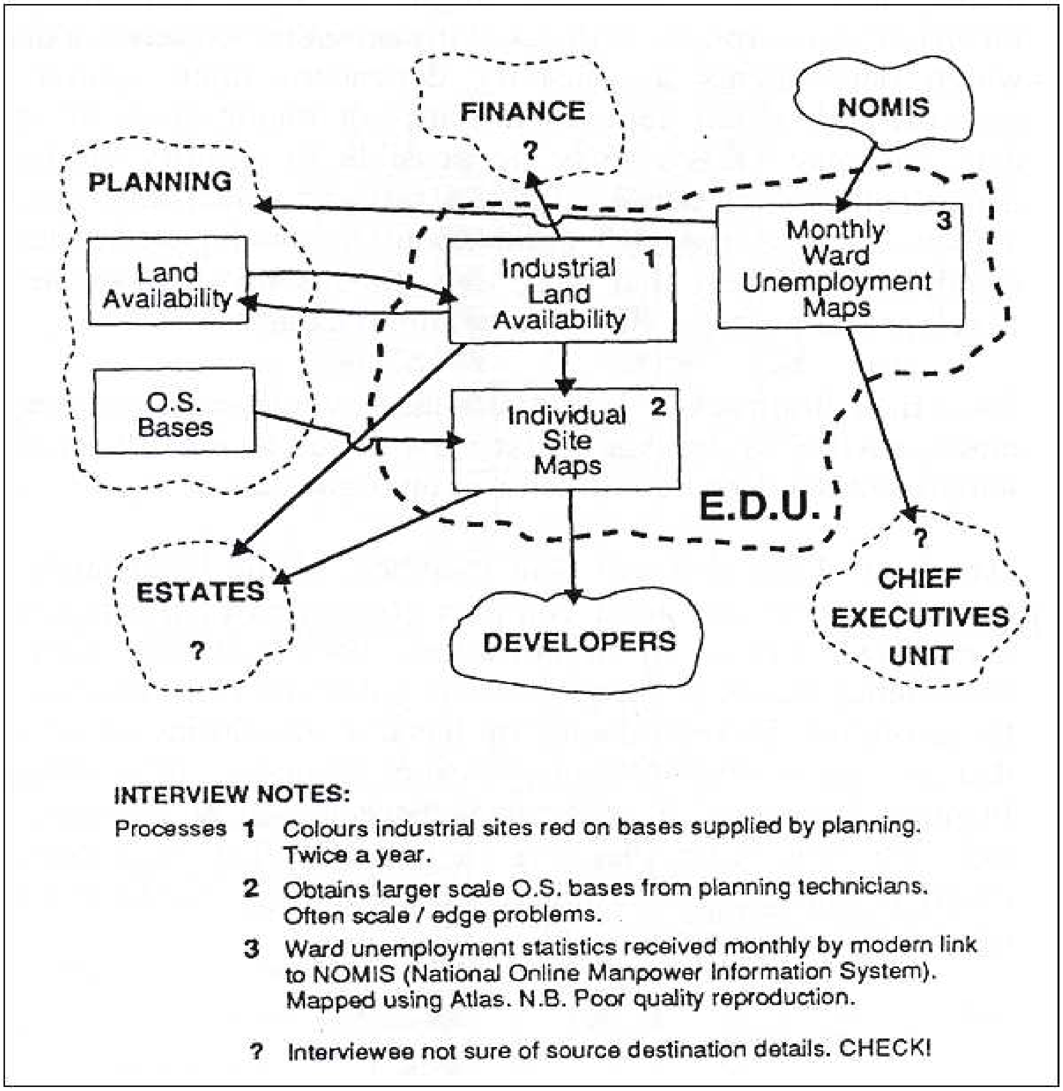

Figure 4.2: Data flow diagram

(from Reeve, 1998:96, Figure 18)

Reeve (1998:97) gives the following four broad perspectives that a UNS should cover, namely:

- Spatial information product requirements examines the current spatial data that the organisation acquires and uses to create the spatial data to fulfil its needs, and who in the organisation creates and uses the data. Reeve (1998) also mentions that here future needs can be identified. Korte (2001) states that while the team is collecting information on spatial data needs and uses, it should also determine the costs of acquiring and creating spatial data.

- A spatial data holdings investigation determines what spatial data are located where in the organisation. This is an inventory of the different spatial data sets, their location, metadata of the data sets, compliance to standards and who is responsible for the maintenance of the sets.
- Preliminary specification of GIS functionality deals with the types of GIS functions required to create spatial data sets that will fulfil the organisation's needs. These functions can range from simple spatial operations, to digitising, to complex spatial analysis that could include geo-statistics, to network and accessibility analysis capabilities. The functions can be grouped into common and specialist functions, which can in turn give guidance on personnel issues such as recruiting and/or training. Buffalo City identified four different types of GIS users, namely the GIS sponsor (executive sponsor), GIS manager (the champion), GIS experts and GIS end-users (Kjörneberg, 2002).
- Attitudes towards GIS: This determines who in the organisation will or will not support the implementation of, or change in, the existing GIS. This perspective is important since it will guide to the implementation team on how to implement change management to manage the personnel during the implementation. The Training of the different users in the value of GIS as done by Farrant (2006) during the implementation of the GIS in Buffalo City is an example of change management.

Buffalo City used different working groups representing different departments which use GIS to assist with the user requirement analysis. These technical working groups conducted the user requirements using a questionnaire, as mentioned by Reeve (1998), and reported to the GIS steering committee. The technical workings groups are also responsible for rolling out the GIS into the different departments (Kjörneberg, 2002).

During the Buffalo City user requirement analysis, the placing of the GIS within the municipality was discussed, i.e. whether it should be in Management Information Services, Land Information Services reporting to Planning and Economic Development, Corporate Services Directorate where it currently is, or at City Manager's level as mentioned above (Kjörneberg, 2002 and Farrant, 2006). The end result of a user requirements analysis is a general design of the GIS. This is a conceptual model of the GIS that describes the system components needed to full the different functions of the organisation and represents the information usage and the flow of information through the system (Huxhold and Levinsohn, 1995).

An alternative approach to the traditional user requirements analysis is to use the Soft Systems Analysis developed by Checkland to understand the GIS needs of the organisation (Reeve, 1998).

Figure 4.3 shows the different stages of Soft Systems Analysis starting with the problem situation in the first stage. The second stage is an attempt to express the problem by drawing a Rich Picture, which is a drawing showing the structures involved, the processes and lines that show the interaction between structures and processes. The first two stages involve everybody in the organisation and the implementation team. At the third stage the implementation team identifies the different systems and root definitions based on different viewpoints and the information from the Rich Picture. The root definition is a sentence which describes the system from a specific viewpoint.

The sentence should identify the **c**lient, the **a**ctors, the **t**ransformation, the viewpoint (**W**eltanschauung), the **o**wnership and the **e**nvironmental constraints (CATWOE) of the system. The root definitions are discussed with the members of the organisation who participated in stages one and two to agree on the context of the root definition. Once the root definition(s) has been agreed upon, the conceptual model is developed in stage four. In stage five the conceptual model is measured against the Rich Picture and refined, which could include refining the Rich Picture as well. These actions will lead to several iterations until a satisfactory conceptual model has been developed. In stage six the conceptual model is discussed and feasible changes within the culture of the organisation are identified.

Once the conceptual model has been created, the implementation team has to do a cost-benefit analysis to provide them with information whether to continue or to stop the implementation. The cost-benefit analysis is discussed briefly in the next section.

4.3.2.1.4 Cost-benefit analysis

The previous section looked at the user needs analysis and the resultant general design (conceptual model) of the GIS meets the organisation's needs. Based on the general design, a cost-benefit analysis should be conducted to establish whether it is feasible to establish a GIS in the organisation. The cost-benefit analysis can be seen as a Stop-Go phase of the implementation process based on the result of the cost-benefit ratio (Bernhardsen, 2002).

Reeve (1998) mentions that cost-benefit analysis has its shortcomings since it tries to quantify those aspects of using a GIS that cannot be quantified. It provides the implementation team with a form of quasi-scientific rationale to convince the decision makers that GIS is a good investment. Bernhardsen (2002) makes a clear distinction between the tangible and intangible costs and benefits when the results are presented. Bernhardsen (2002) gives a ranking guide to rank the intangible costs and benefits in terms of effect and realisation. Both results should be presented to the decision-makers to establish whether the implementation should proceed or not.

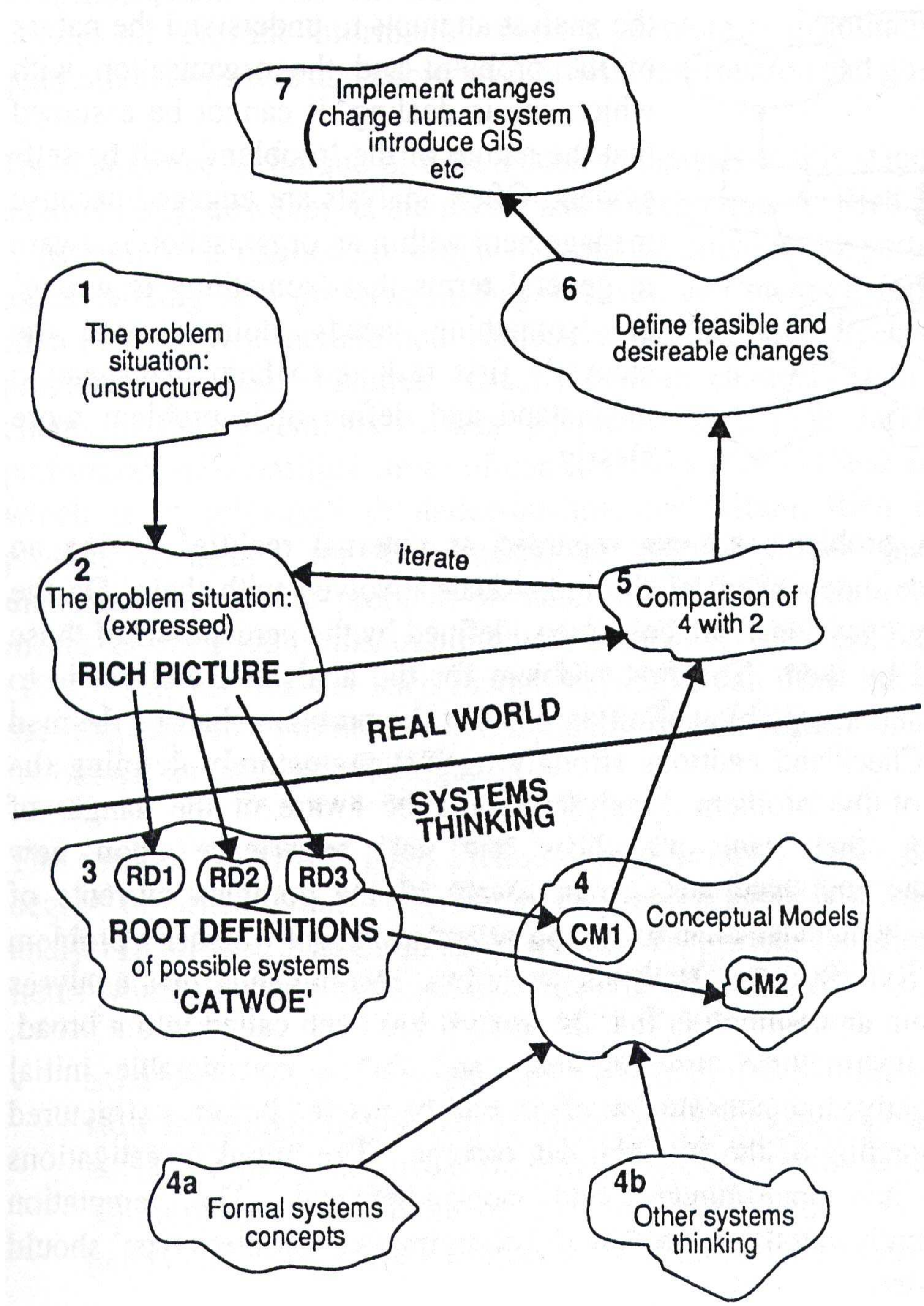

Figure 4.3: **The different stages of the Soft Systems Analysis method**

(from Reeve, 1998:173, Figure 29)

The theoretical basis of a cost-benefit analysis is to establish whether a business can improve its internal efficiency and productivity by implementing a new technology such as GIS, and public organisations aim to improve their internal efficiency and their external effectiveness (Bernhardsen, 2002). The latter is known as socioeconomic costing (Bernhardsen, 2002). Bernhardsen (2002:340) lists the following ten phases of a cost-benefit analysis:

- *“Define different projects/alternative actions.*
- *Establish assumptions for calculation: time perspective, rates of interest, etc.*
- *Chart the positive and negative effects of various project alternatives.*
- *Quantify the effects (i.e. cost and benefit).*
- *Calculate the cost-benefit ratio.*
- *Consider the non-quantifiable effects.*
- *Carry out a sensitivity analysis if necessary.*
- *Recommend or choose solutions.*
- *Establish prerequisites (preconditions) for the realisation of gains.*
- *Work out strategies or plans for the realisation of gains (including budget proposals).”*

Points 1 to 3 can be determined form the user requirements analysis and the general design of the GIS.

Determining the costs is a relatively straightforward process (Reeve, 1998 and Bernhardsen, 2002), but the cost items are sometimes difficult to identify, since some of the cost components are not always immediately apparent (Reeve, 1998 and Bernhardsen, 2002). Bernhardsen (2002) states that socioeconomic costing adds a further complication since the complete effect cannot be defined concisely and thus the actual cost cannot be determined. Costs can be classified under the following categories (Reeve, 1998 and Bernhardsen, 2002):

- Planning costs such as personnel and consultant costs (these figures can be obtained from the costs of establishing the implementation team, planning and user requirement analysis) and design costs.
- Establishment costs, which include procurement, data conversion and other data, start up, application development, and hardware and software costs.
- Operations costs such as internal personnel costs of training, operations, user support, etc., external consultants, on-going costs such hardware, software and data maintenance costs, cost of capital, insurance, office space and consumables.

Bernhardsen (2002:341) also lists the following intangible liabilities:

- *"Increased vulnerability due to reliance on computers, which may fail because of hardware and software malfunctions or failures, or the system can be compromised by a computer virus.*
- *Poorer working environment, due to equipment-generated noise, tedious digitising tasks.*
- *Increased entry-level competence, which can bar some staff members."*

Reeve (1998) cautions that although it may seem that the costs are obvious, they are not, and care should be taken to achieve a balanced cost estimate for the implementation of a GIS.

According to Reeve (1998), it is more difficult to quantify benefits than costs and care should be taken with the processes involved in calculating the benefits. Antenucci *et al.* (1991), as referenced by Reeve (1998:105-9), grouped potential GIS benefits into five types:

- Type 1: Quantifiable efficiencies in present practices such as reduction in staff hours to complete a task and reduced costs in terms of materials, etc. (Bernhardsen, 2002). Another measure for type 1 is to determine avoidable cost, such as the cost of redrawing paper maps when new information becomes available compared to the use of a GIS (Reeve, 1998). The result is faster processing times, which translates into benefits in products and services (Bernhardsen, 2002). Other benefits are improved internal and external communication with other users, and due to improved quality, clients have less work to do on the product they receive (Bernhardsen, 2002).

- Type 2: Quantifiable expanded capabilities, which could be done if a GIS were implemented, which with the present manual system are too costly to create. This gives the organisation the opportunity to create new products, thus enlarging the range of products available to the customers (Reeve, 1998). The benefit can be quantified by comparing the cost of creating the product manually and the cost of doing so in a GIS (Reeve, 1998).
- Type 3: Quantifiable benefits from the sale of new products or services: due to type 2, the organisation can sell new products (Bernhardsen, 2002), or due to improved quality or faster service the organisation can charge a higher price.
- Type 4: Intangible, unquantifiable benefits, which Reeve (1998) argues is very difficult to translate into monetary value. Bernhardsen (2002) says that the implementation team should note all the intangible benefits, both negative and positive, and present them together with the quantifiable part of the cost-benefit analysis. Examples of intangible, unquantifiable benefits are: "*improved self-esteem, increased staff morale, higher-quality goods and services, more conclusive decisions, more rapid decisions and greater job satisfaction*" (Reeve, 1998:108 and Bernhardsen, 2002:341-2).
- Type 5: Unquantifiable, unexpected, intangible benefits are those that were not anticipated, such as the development of trust between researchers and users and between different departments, which result in improved outputs and the generation of new knowledge (Reeve, 1998).

Bernhardsen (2002:345) gives the following four categories in which the intangible effects (negative and positive) can be classified. Each category may carry a different weighting and a final score can be given for the intangible effects. The categories are:

- Great effect and good chance of realisation.
- Great effect but slight chance of realisation.
- Little effect and slight chance of realisation.
- Little effect but good chance of realisation.

The base method for analysing the quantifiable part of the cost-benefit analysis is: the quantity x the unit price = benefits (or costs) (Bernhardsen, 2002). Bernhardsen (2002) also states that time should be factored in and that the effect of interest should not be left out of the calculations. The effect of interest can be discounted by assessing future values in terms of present values. The interest rates are higher for high-risk or short-term projects. When calculating the final values, the project lifetime should also be factored in for GIS projects with a time horizon between 10 to 20 years (Bernhardsen, 2002). These values are then used to determine the cost-benefit ratio, which is the present value of benefits divided by the present value of costs (Bernhardsen, 2002). Bernhardsen (2002) gives the following rule-of-thumb to decide whether the implementation process should proceed or not:

- A cost-benefit ratio of 1:2 or more: the GIS should be implemented.
- A ratio between 1:0.8 and less than 1:2: the project should be analysed again with the aim of reducing costs where possible.
- A ratio of less than 1:0.8 indicates that the implementation of the GIS should not proceed and the process should be stopped.

The above findings should be presented to top management with an evaluation of the intangible costs and benefits as discussed previously. The risks involved in implementing the GIS should also be stated. The risks can be classified into three categories (Reeve, 1998):

- Size risk – The more staff and departments involved, the more projects will be included in the pilot study or the prototyping, therefore the greater the risk.
- Structure risk – The bigger the organisational change, the more managerial support needed and the more changes in job descriptions, so the bigger the risk.
- Technology risk – The more novel the GIS and related hardware combined with a lack of experience of the implementation team, the greater the risk.

If the cost-benefit analysis and risks indicate that the implementation should proceed, the actual design of the system that will fulfil the needs of the organisation is done. The design of the system is discussed in the next section.

4.3.2.1.5 Design

The design of the system draws on the user requirements analysis and the general design as a basis for the detail design (Huxhold and Levinsohn, 1995). Reeve (1998) states that it is important to take soft issues into consideration when designing the system, and recommends that Multiview, which was developed by Wood-Harper, Antill and Avison in 1985, should be used when implementing the GIS. Multiview is discussed briefly since Hobson (1991), as referenced by Reeve (1998), maintains that Multiview is good a model to use when developing and implementing a GIS as it takes the human factor into account.

Multiview approaches system development from five different perspectives (Figure 4.4):

- The Human Activity System: The question that needs to be answered is how the information system is to further the aims of the organisation, which is obtained from the user requirement analysis. Another approach, which can be used when conducting a research in understanding the problem, is to use Checkland's SSA methodology (Reeve, 1998). Checkland's SSA methodology is discussed in Section 4.3.2.1.3.

- The Analysis of Entities and Functions: This is based on the results of the general design, which is now progressively further broken down into necessary sub-functions to enable the system to fulfil the needs of the particular organisation.
- The Analysis and Design of the Socio-technical System: Here the implementation team designs a system that is a "good fit" between the needs of the users and the technical aspects of the system.
- Design of Human-Computer Interface: Based on the above, the technical aspects of the system are now developed to enable interaction between humans and the computer. Examples are menu-driven systems, command line systems and mouse/windows interface together with proper help screens to assist users.
- Design of the Technical Subsystem: Here the subsystems of the GIS are developed, which will efficiently and effectively meet the functional requirements of the different users.

DeMers (2000) discusses the Marble Spiral Model, which can be used for rapid prototyping of a GIS. The model consists of three sectors:

- Acquire information.
- Analyse information.
- Organise information.

The process starts with the initial model in the acquire information sector and spirals through analyse-the-information sector and then through organise-the-information sector. Once the spiral again reaches the acquire information phase, it becomes a conceptual model, which is based on the results of organised information in the previous sectors. The conceptual model then spirals through the sectors until it becomes the detailed model and the detailed model spirals through the sectors until it becomes the system implementation (DeMers, 2000). Figure 4.5 gives a schematic view of the spiral model.

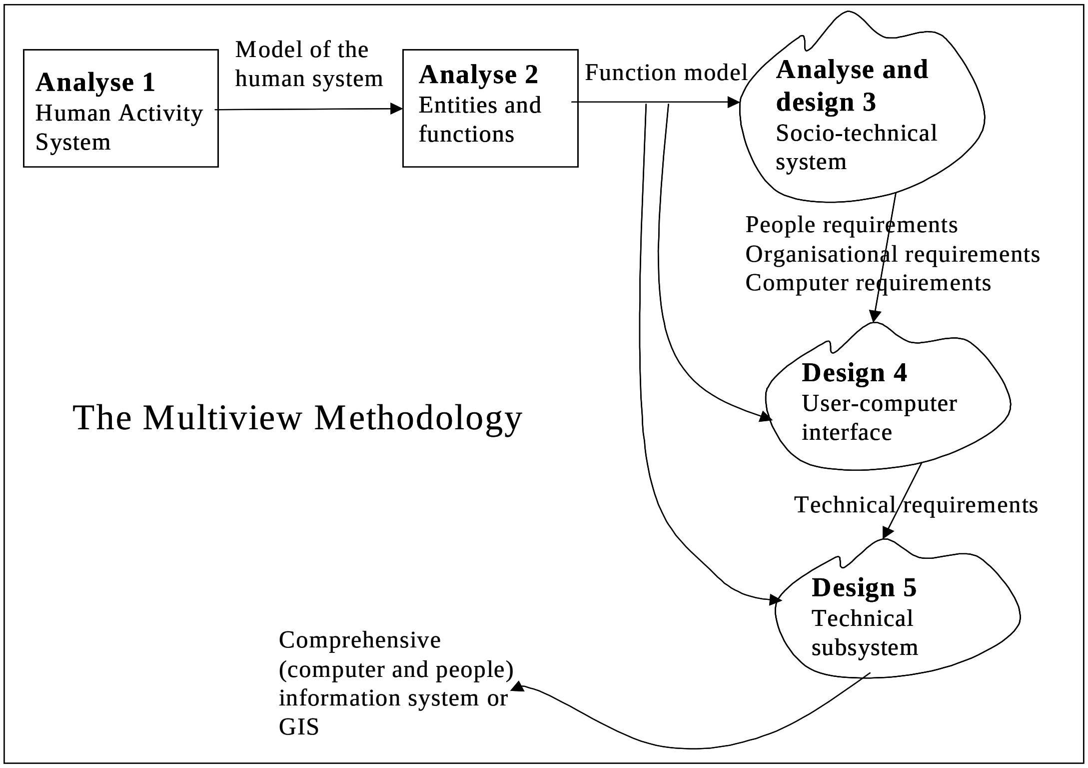

Figure 4.4: The Multiview methodology

(from Reeve, 1998:192, Figure 34)

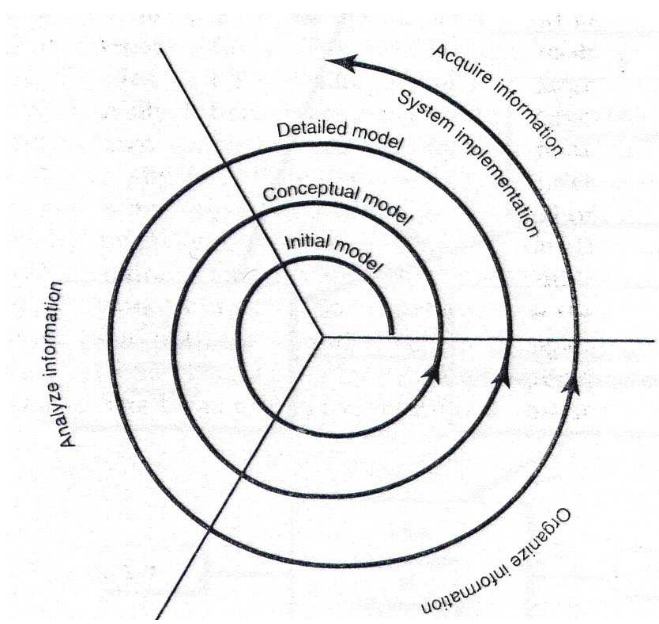

Figure 4.5: The spiral model for rapid prototyping by Marble

(from DeMers, 2000:449, Figure 15.5)

In this stage the final GIS has been designed to fulfil the needs and requirements of the organisation. The next phase is the acquisition and development of the designed system.

4.3.2.1.6 System acquisition and development

Once the design has been finalised, the system must be acquired and developed for implementation throughout the organisation. During system acquisition, staff have to be trained to use the GIS once it has been implemented. Training is discussed separately from this section. Huxhold and Levinsohn (1995:176) state that the type and quantity of software, hardware and peripherals depend on the following main factors:

- *"The business of the organisation and the size of the organisation*
- *The culture and philosophy of the organisation with respect to contracting or undertaking work internal to the organisation*
- *The scope of the project*
- *Data already in existence within the organisation or available from other sources*
- *The type and nature of the applications."*

Huxhold and Levinsohn (1995) indicate that an organisation that wishes to implement a GIS can use consultants to assist with acquisition and implementation of the system, especially where the organisation lacks specific skills that must still be acquired. Both Huxhold and Levinsohn (1995) and Bernhardsen (2002) describe a process for the acquisition and development of a GIS, which could include the following aspects:

- *"Pilot project*
- *Design requirements*
- *Choice of hardware and software*
- *System implementation*

- *Technical database design*
- *Creating databases*
- *Operation and maintenance*
- *Safekeeping and security*
- *Evolving new applications".*

These aspects given by Bernhardsen (2002:361) are fairly similar to the aspects discussed by Huxhold and Levinsohn (1995), apart from the different order of listing. Huxhold and Levinsohn (1995) give the following aspects which are not listed explicitly by Bernhardsen (2002):

- Demonstrations and presentations, and
- Project reporting.

These aspects of acquisition and development are discussed briefly below.

a) The pilot project

Huxhold and Levinsohn (1995:196) argue that pilot projects can assist with the understanding of the system, which could include training, the reduction of risk and uncertainty as well as determination of the impact on the organisation and its functions. Another advantage of using pilot projects is that they can assist in choosing a better system(s). The pilot project could also form part of the benchmarking process to test various production methods and processes and to assist in identifying possible system faults that can then be rectified, without causing severe disruptions of functions in the organisation (Bernhardsen, 2002).

A pilot project is a small-scale implementation of the designed system and its subsystems, with all its identified functions and applications, hardware, software and peripherals. It is thus a representation of the full-scale GIS. Bernhardsen (2002) argues that ideally two geographical test areas should be chosen, one which is very complex and one which has a low level of complexity. These two geographical areas will provide a sound test bed to test the pilot project.

Once the pilot project has been identified, the implementation team should decide on who will be responsible for the acquisition and development of the GIS using the pilot project as a base line. The implementation team can decide whether the organisation should retain system responsibility during the acquisition and development phase as well as during the final implementation of the GIS, or should system responsibility should be outsourced to the chosen suppliers (Bernhardsen, 2002).

b) Design requirements

The design requirements are based on the user requirements analysis as discussed in Section 4.3.2.1.3 and on the final design of the system as discussed in Section 4.3.2.1.5. The design requirements for software, hardware and peripherals such as plotters, digitisers and printers, are included in the request for proposal (RFP) sent to the vendors by the organisation. Design requirements serve a two-fold function: they inform potential vendors about the needs of the organisation which the organisation can use as a control measure for establishing contract compliance. System specifications are based on the design requirements and should cover hardware, software, maintenance, training and costs (Bernhardsen, 2002).

c) Choice of hardware and software

Based on the RFPs from different vendors, the organisation has to evaluate the proposals to choose the most appropriate software and hardware. Huxhold and Levinsohn (1995:186) propose the following steps based on Antenucci (1992) as referenced in Huxhold and Levinsohn, 1995):

- Review of responses received from various vendors to evaluate their general compliance with the requirements of the RFP
- Initial ranking of received RFPs based on the response review

- Rigorous review of the top-ranked RFPs, which could include oral responses by the vendors, benchmarking, visits to the vendors and to their clients who use their systems and reference checks
- Cost review and possible re-ranking based on costs
- Selections of hardware and software and recommendations are presented to management based on well-documented evaluation processes and results.

Once the final vendor or vendors have been selected, a contract is negotiated between the organisation and the vendor or vendors. Different vendors for software, hardware and peripherals can be selected by the organisation. Bernhardsen (2002:371) points out that the contract should be mutually acceptable, clear and complete. The contract should have guidelines on confidentiality and on the treatment of late and non-deliveries of contracted goods (Bernhardsen, 2002). Bernhardsen (2002:372) states that the contracted vendor or vendors should fulfil the contract regarding:

- Installation
- Customisation, database design, etc.
- Acceptance testing of specified requirements and determining that functions are also in conformance with the contract.

d) Technical database design

Bernhardsen (2002:372) maintains that the database should be able to support the functions that have been designed and the scope of the project should ensure that no redundant data are captured. It must also be determined whether the data can be easily accessed and that the function can be executed efficiently and effectively. The users must be able to maintain the data, the database must be able to receive new data and the data must be easily restructured in the database should the need arise.

DeMers (2000:456) gives the following guidelines on database design when determining the scope of the project:

Determine the study area, which will guide the type of data needed.

- Determine the scale, resolution and level of detail of the different data sets available for the study area. The “best available data” approach is often used.
- Determine classification levels for the study area. DeMers (2000) indicates that it is easier to aggregate classes than to disaggregate them.
- Coordinate system and projection for the study area. The GIS has the capability to do transformations from one coordinate system and projection to another, but if it is done to often, errors occur. Transformation exercises should be kept to a minimum (DeMers, 2000).

When creating the technical design, the following design constraints should be taken into consideration: the logical database design which is governed by the software and the physical database design which is influenced by the hardware. If these two constraints are taken into account as well as the aspects regarding scope, access to data, etc. as discussed above, a proper database will be designed to support the identified functions of the GIS (Bernhardsen, 2002).

e) Creating databases

As the creation of databases is a costly and time-consuming exercise, which can take up to 80% of the project time, a technically well-designed database is essential to ensure a good quality database which will function as efficiently and effectively as possible. To keep the momentum going with regard to implementation of the GIS, it is good practice to load the important data sets first to enable rapid access to them as soon as possible. The organisation can also outsource some or most of the database development and database population activities such as the digitising of paper maps or routine tasks that would place an extra burden on in-house staff members (Bernhardsen, 2002). If the organisation decides on an enterprise-wide GIS, it should develop a data warehouse in which it can store much more data than in a normal database. Green and Bossomaier (2002:167) define a data warehouse as follows:

> *"A data warehouse is an organised collection of databases and processes for information retrieval, interpretation and display."*

A geographic data warehouse consists of a combination of spatial layers, models and metadata (Green and Bossomaier, 2002). According to Green and Bossomaier (2002), a data mart or local data warehouse is a smaller version of the data warehouse with the same characteristics, but it serves only a single functional unit within the organisation. They identified three different types of geographic data warehouses (see also Figure 4.6):

- An enterprise data warehouse, which combines the data from various sources including metadata into a single data warehouse that serves the entire organisation.
- An independent data mart, which consists of several small data warehouses distributed over the organisation, and which can draw from the same source, thus having the disadvantage of duplicating data sets.
- A dependent data mart is a sub-set of an enterprise data warehouse that serves a specific functional area of the organisation. All the data in the organisation feeds into the enterprise data warehouse as in point 1.

The design of a data warehouse is similar to the design and implementation of a GIS to enable it to fulfil the data needs of the organisation (Green and Bossomaier, 2002).

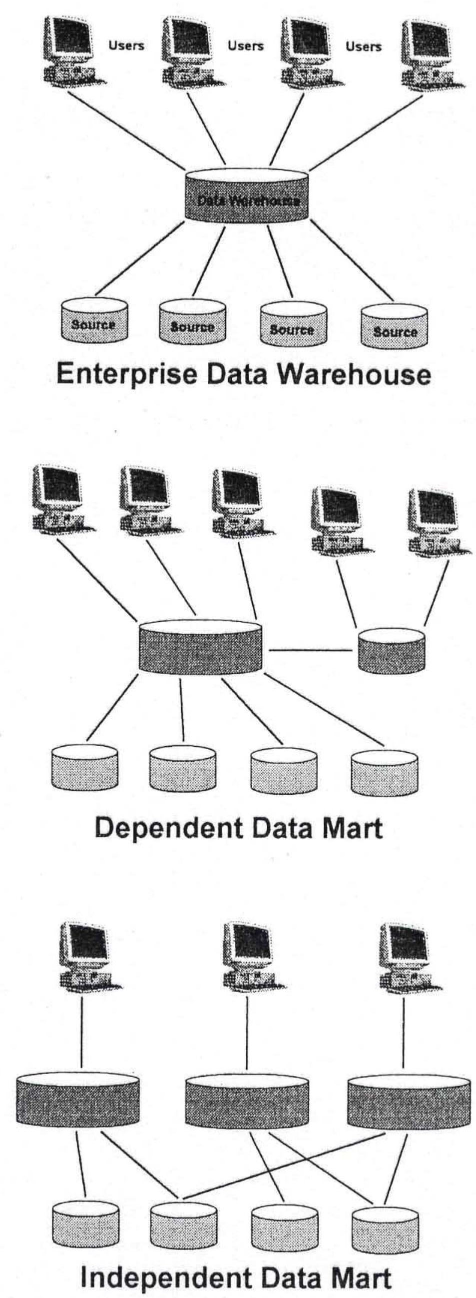

Figure 4.6: Different types of data warehouses and data marts

(from Green and Bossomaier, 2002:171, Figure 10.2)

f) Operation and maintenance

Bernhardsen (2002) states that during database design, the maintenance of the data should be factored in as discussed in the technical design sub-section above. The maintenance of the data is based on the maintenance cycle of the data set, such as annually, or every two or three years. The cycle depends on the nature of the data used. Various maintenance options can be used, such as people working directly with the data to a person who is responsible for version control by using temporary data storage before the most current dataset is placed in the database (Bernhardsen, 2002).

g) Safekeeping and security

Bernhardsen (2002) emphasises the need to have access control to the data, especially sensitive data, to secure the servers and other computer hardware against computer virus infections. He also recommends that proper version control and back-ups should be made of the data that is stored in a data warehouse. He recommends that when working with the data, a copy of the original should be used and all back-ups and original data sets should be stored on a medium such as DVD or removable hard disk which is stored separately in fireproof safes to prevent the data from being destroyed. All the above aspects must be taken into account during system acquisition and development, and could even include the acquisition of two fireproof safes.

h) Evolving new applications

Owing to the changes that are made when a GIS is implemented in an organisation, new applications will evolve over time and this possibility should be factored in when developing the GIS. It should be flexible to accommodate the new applications. The new applications may follow the same steps as those that were followed when the system was initially implemented, such as user requirements analysis, cost-benefit analysis, etc. (Bernhardsen, 2002).

i) Demonstrations and presentations

Huxhold and Levinsohn (1995) maintain that the implementation team is at risk of getting so involved with the acquisition and development of the GIS that other staff members who will use the system in the end may loose interest if they are not kept up to date with developments. To minimise the risk, Huxhold and Levinsohn (1995) suggest that presentations should be made to report on progress. Once the GIS has been developed, it is good practice to run a few demonstrations, using some of the organisation's own data, on what the GIS is capable of delivering. Adequate time and resources should be planned and allocated for presentations (Huxhold and Levinsohn, 1995).

j) Project reporting

Huxhold and Levinsohn (1995) emphasise the importance of project reporting. The level of detail of the project report depends on the target audience. Top and senior management would like to have a general understanding of the progress of the project, problem areas and how these are being addressed, whereas the project manager needs a detailed report to monitor the process as well as for auditing purposes. Presentations and demonstrations as discussed in the previous sub-section can be used as part of project reporting to other staff members (Huxhold and Levinsohn, 1995).

4.3.2.1.7 Implementation

Once the GIS has been developed and tested, revisions can be made to fine-tune it before implementation of the revised GIS throughout the organisation. When it is finally implemented, the final implementation plan must be communicated throughout the organisation to inform the staff about what is happing. The final implementation plan should include the following:

- Implementation schedule;
- Training schedule, including career path development;

- Creation of the GIS support services;
- Personnel support during the implementation;
- Change management procedures; and
- Project status and feedback schedules.

The above points are based on Huxhold and Levinsohn (1995) and Somers (1998). Huxhold and Levinsohn (1995) also indicate the importance of having a flexible implementation plan so as to incorporate critical issues that may have been missed during the previous phases. These issues can be dealt with in the project status and feedback sessions that are scheduled during implementation.

4.3.2.1.8 Training

When a GIS is implemented in an organisation, training of staff forms an integral part of the implementation process (Huxhold and Levinsohn, 1995; Somers, 1998; Korte, 2001; Bernhardsen, 2002 and Farrant, 2006). Training can be divided into three types, namely:

- Educating the users. According to Somers (1998), this is closely linked with the implementation stages discussed above, during which the implementation of a GIS is mentioned as an option for the organisation to fulfil its needs, through user requirement analysis, cost-benefit analysis, design and development. This is done via workshops, short training sessions and working groups. The latter provide the platform for the future users to give inputs into the implementation process (Somers, 1998). Farrant (2006) mentions that as part of the GIS implementation in Buffalo City, short training sessions were conducted with managers and city councillors, which promoted continued buy-in into the GIS implementation process.
- Formal training of the users. This should be scheduled well in advance of the implementation of the GIS to ensure that once the GIS has been implemented the users are able to use it (Somers, 1998 and Korte 2001). Bernhardsen (2002) states that as an option the organisation could

outsource the training of managers and personnel to ensure that the new system will be utilised effectively. Inadequate training can lead to frustrations and eventual failure of the implementation (Korte, 2001 and Bernhardsen, 2002).

- Continuous training. This is necessary once the initial training is complete. Systems are maintained on a regular basis, which include software and hardware upgrades. Upgraded software includes new functionalities, which benefit the organisation and its changes in data management, such as the changes ESRI introduced when migrating from ArcInfo and ArcView to the ArcGIS suite. This may necessitate intensive training of staff to enable them to use ArcGIS efficiently and effectively. Training of new staff members who replace staff who leave the organisation is also necessary (Korte, 2001).

Sections 4.3.2.1.1 to 4.3.2.1.9 discussed the various processes and issues regarding the implementation of a GIS in an organisation. These include choosing the implementation team, the user requirement analysis, and the development and implementation of the GIS, which provide the background for implementation management. The next section discusses the management of the implementation process starting with the management of the implementation team.

4.3.2.2 Management at the implementation team level

As mentioned in Section 4.3.2.1.1, the implementation team is responsible for driving the GIS implementation in the organisation. The GIS champion (who is the project manager) and the steering committee (if one is established) manage the implementation team. The team produces reports on a regular basis to inform both executive management, via the executive sponsor, and the organisation itself. Part of the management process is to ensure that the implementation team adheres to deadlines, and if there are problems the team receives guidance from the GIS champion and/or the steering committee to get the implementation process back on track (Farrant, 2006).

Other management issues are the assignment of who in the implementation team is responsible for the policy, budget and strategic decisions; implementation management; the selection of the technology and the implementation of alternative technologies if the need arises (Huxhold and Levinsohn, 1995). According to Bolstorff and Rosenbaum (2003), the implementation team can co-opt other members of the organisation to assist them with different implementation tasks. Huxhold and Levinsohn (1995) give an example of a management framework which the implementation team can use to help them identify role-players and associated management issues.

Table 4.1: Example of a management framework

(based on Huxhold and Levinsohn, 1995:97, Table 4.2)

Framework element	**Participants**	**Responsibility**	**Meeting structure and frequency**	**Reporting**
Management authority (steering committee, implementation core team).	Policy makers or departmental heads, including GIS champion, core members and executive sponsor.	Policy decisions. Approval of plans and resource allocation. Conflict resolution.	Quarterly. More frequently at key milestones of the project or if issues arise.	The core implementation team reports to executive and to the organisation.
Implementation team (Huxhold and Levinsohn's liaison committee).	The implementation team.	Project monitoring. Communication. Coordination of the implementation process.	Quarterly or if issues arise that need to be addressed.	Implementation team.
Implementation sub-team. User working group (s) if selected and co-opted.	Line managers and senior professionals as well as selected implementation team members.	Assist and/or facilitate the user requirement analysis and the designing of the system.	Weekly to monthly based on project workload or project milestone.	As a group to the implementation team and if required on an individual basis to management.
Design and implementation (sub-group of the implementation team).	Project leader (which could be the GIS champion) and selected implementation team members.	Technical design of the system. The development of the system. System testing and refinement.	Daily to weekly. Short meetings.	Project team of the sub-group.
Implementation project management team.	GIS champion, executive sponsor and core members of the implementation team.	Preliminary GIS plan. Project plans and deliverables. Coordination. GIS implementation.	Daily to weekly. Short meetings.	As a team reporting to executive, the full implementation team and the organisation.

Huxhold and Levinsohn (1995) stress the importance of managing expectations as well as change when a GIS is implemented in an organisation. This is seen as one of the most important activities of the implementation team. The primary activity of the implementation team is to plan the GIS and the management thereof, which will be explored in the next sub-section.

4.3.2.3 Managing the planning of the GIS

At this stage, as mentioned in Section 4.3.2.1.2, the planning of the GIS provides the organisation with a preliminary plan of the implementation process that will be followed with implementation of the GIS in the organisation. When drawing up the preliminary implementation plan of the GIS, two aspects must be managed, namely establishing the scope of the GIS and the management of the drafting of the preliminary implementation plan.

With regard to the management of the scope of the GIS, the project team must manage the scoping process, i.e. it must convene the appropriate members, draft the scope, including milestones and deadlines, and write the report and distribute it for comment. The incoming comments must be managed to ensure that all replies are captured within specified time frames. The final management issue is the distribution of the final scope based on the input from the implementation team and inputs from the organisation. Management issues could include the final format of the report, which includes the scope, as well as the determination of deadlines and the appointment of a dedicated person to write the scope and to document the process.

Once the scope of the GIS has been identified, the preliminary implementation plan of the GIS is drawn up. There are a number of management requirements for drawing up the preliminary implementation plan.

The first requirement is the content of the preliminary implementation plan. Huxhold and Levinsohn (1995) and Bernhardsen (2002) state that a well thought out implementation plan helps the implementation team to identify possible problems that may arise and to determine pro-actively measures to deal with these problems. It also builds the confidence of the executive with regard to the implementation of a GIS and gives guidance to the organisation on how the GIS will be implemented. Huxhold and Levinsohn (1995:92) give the following outline of the contents of a plan:

- The plan should have an introduction to introduce the content and overall reason for the implementation of the GIS. An interim work plan and project phases should be provided until the proper implementation plan has been finalised.
- As a background, the strategic vision of the organisation and an overview of how a GIS may help the organisation to achieving its vision should be stated, as well as what has been done up to now, such as the selection of the implementation team, etc.
- The scope of the project and the objectives. Possible constraints on the implementation process such as the organisational set-up, budget, etc. should be stated.
- The participants in the process, such as the implementation team and their responsibilities.
- A description of the overall implementation tasks and milestones as well as the immediate tasks concerned with planning the implementation. The results of each milestone must be given.
- The implementation schedule, using tools such as Gantt charts to show the different project phases and tasks.
- A preliminary overall budget for the implementation process, which should include attending conferences and site visits by the implementation team.

The second management requirement is to determine who on the implementation team is responsible for drawing up the preliminary GIS implementation plan. It is useful to assign a person to draft the plan, with the rest of the implementation team providing input.

The setting of deadlines for the writing the plan and when the plan will be communicated to the organisation is the third requirement.

The fourth requirement is the scheduling of feedback sessions on each step of the implementation process as described in the plan.

The publishing of the final preliminary plan is the last requirement to be met.

4.3.2.4 Managing the user requirement analysis

The user requirement analysis is one of the steps included in the preliminary implementation plan of the GIS, which will provide the implementation team with the necessary information on the design of the GIS to fulfil the needs of the organisation. Reeve (1998) recommends that the GIS champion should project management the user requirement analysis.

The following aspects of the user requirement analysis should be managed:

- The selection of team members and possible user workgroups which will conduct the user requirement analysis. GIS professionals (internal to the organisation and/or contracted professionals), departmental managers and experienced staff should be part of the team.
- The selection of the user requirement analysis approach, either the informal or formal approach as discussed in Section 4.3.2.1.3, as well as the tools used to do the analysis such as grid charts (see Figure 4.1) and the Soft Systems Approach developed by Checkland as shown in Figure 4.3 (Reeve, 1998).
- The scheduling of interviews of the identified departments as per the implementation plan (Section 4.3.2.3) by the identified team members.
- Determining the deadline of the draft report on the user requirement analysis and the responsible team member to coordinate the report.
- Scheduling of feedback sessions with the relevant departments.
- Determining the deadline and release of the final user requirement analysis report.

Once the user requirement analysis has been completed and a conceptual design of the GIS has been developed based on the results, the implementation team will be in a position to conduct a cost-benefit analysis of the proposed GIS that will be implemented in the organisation. Korte (2001) recommends the use of a GIS professional consultant to assist with the implementation of a GIS. The GIS professional has experience of implementations and can steer the organisation around common pitfalls, provide objective inputs on the user requirement analysis since he or she is not directly involved with the organisation, and provide project and change management support to the organisation during implementation.

4.3.2.5 Managing the cost-benefit analysis

Bernhardsen (2002) is of the opinion that a successful GIS implementation is the result of a carefully executed cost-benefit analysis. An in-depth cost-benefit analysis must be managed properly to ensure that all the aspects are covered as best as possible. Section 4.3.2.1.4 discusses the different aspects of the cost-benefit analysis as well as the different phases involved. The ten phases of a cost benefit analysis are repeated in this section as a guide to the management of a cost-benefit analysis (Bernhardsen, 2002:340):

- *"Define different projects/alternative actions.*
- *Establish assumptions for calculation: time perspective, rates of interest, etc.*
- *Chart the positive and negative effects of various project alternatives.*
- *Quantify the effects (i.e. cost and benefit).*
- *Calculate the cost-benefit ratio.*
- *Consider the non-quantifiable effects.*
- *Carry out a sensitivity analysis if necessary.*
- *Recommend or choose solutions.*
- *Establish prerequisites (preconditions) for the realisation of gains.*
- *Work out strategies or plans for the realisation of gains (including budget proposals)."*

The management of these phases could include, but are not limited to, the following:

- The assignment of resources to each phase, including a team leader. Members of the implementation team must be selected, and they can co-opt persons from the organisation to assist them in each project.
- Scheduling the milestones and completion dates of each phase. A Gantt chart can be used to map the schedules.
- Reporting process and the format of the report.
- Scheduling the release of the cost-benefit report which includes the Stop-Go decision.

If the decision based on the cost-benefit analysis is to go ahead with the implementation of the GIS in the organisation, the GIS must be designed to fulfil the needs of the organisation.

4.3.2.6 Managing the design of the GIS

Based on the results of the user requirement analysis and the cost-benefit analysis, the GIS that will be used in the organisation must be designed to fulfil the needs of the organisation. Several approaches can be used to design a GIS, namely System Design Methodology (SDM) as discussed by Huxhold and Levinsohn (1995), Multiview described by Reeve (1998) and the Spiral Model as mentioned by DeMers (2000). The latter two are discussed briefly in Section 4.3.2.1.5.

The first management decision is to decide which method to use to design the GIS, and then the teams must be selected to design the GIS. Team members can be selected from outside the implementation team and the organisation. The design of the GIS is managed using standard project management processes which may consist of and milestones for each phase using tools such as Gantt charts. Feedback sessions should be scheduled with affected groups within the organisation to fine-tune the design.

Based on the feedback, the design of the GIS is released and the GIS and required peripherals are acquired. DeMers (2000) indicates that, by using a structured approach for designing a GIS, design creep can be avoided, which if not properly managed can have an adverse effect on the implementation process.

4.3.2.7 Managing the system acquisition and development

Section 4.3.2.1.6 in Chapter 3 discussed the various aspects of the acquisition of a GIS and possible further developments to the system. These aspects must be managed properly to ensure proper acquisition and development of the GIS. The management of the acquisition and development can be broken down into the following management phases as given in Section 4.3.2.1.6:

- The overall management issue is the selection of the acquisition team, which could include members from the implementation team, procurement and professionals from the vendor from which the GIS is acquired. This team will report to a project leader who is responsible for the project and reports to the implementation team.
- The next aspect that needs to be managed is the decision on the pilot project. The management aspect ensures that the pilot project is representative of full-scale implementation and that the correct pilot test areas are chosen. According to Bernhardsen's (2002) suggestions, an area that has a high level of complexity of data and processing and another area that has a low level of complexity should be selected.
- The management of the design requirements enables the project leader to see that the design specifications as developed in Section 4.3.2.1.5 and managed according to Section 4.3.2.6 are correctly given in the request for proposals (RFP) that are sent out to the chosen vendor(s). The design requirements will also guide the project manager on the management of the system specifications and the acquisition of the correct hardware and software. The management of the RFP could include the following:
    - Ensuring that the RFP reflects the needs of the organisation with respect to design requirements and system specification.

  - Setting up the selection criteria against which the hardware and software will be measured which will be included in the RFP to guide the vendor(s).
  - Scheduling the release of the RFP and the time period given to vendors to respond to the RFP.
  - Scheduling of the evaluation of the received RFPs and feedback to respondent(s) on the outcome of their RFPs. If benchmarking is required, the acquisition team will have to schedule the benchmarking, including the criteria that will be used during the benchmarking activities.
  - Once the final vendor(s) have been selected, the contractual aspects must be managed according to the organisation's procurement guidelines. Bernhardsen (2002) gives guidelines on contract fulfilment (Section 4.3.2.1.6).
- The next management aspect is the management of the design and development of the database which will house the data for the two pilot study areas. DeMers (2000) gives the following guidelines that can be used to manage the technical design of the database: the study area; the scale, resolution and level of detail of existing data sets ; the different classification levels that will be used; and the coordinate system and projection for the study area. More detail on these aspects are given in Section 4.3.2.1.6. Bernhardsen (2002) states that the project manager should keep in mind that the logical design of the database is governed by the software and the physical design is influenced by the hardware. Regarding the creation of a database, the management decision is whether the database should be a stand-alone database or whether it should be a data warehouse. Three types of data warehouses, which are discussed in Section 4.3.2.1.6, can be considered based on the need of the organisation, namely: an enterprise data warehouse, an independent data mart, and a dependent data mart (Green and Bossomaier, 2002). Other management aspects that must be considered regarding database(s) for the pilot project and later for the full implementation of the GIS, are the maintenance management of the data, such as scheduling of

the maintenance, and appointing a person responsible for the management of the database.

- Safekeeping and security of the data must be managed properly to ensure that data sets are backed up at scheduled intervals. Access control to data must be regulated and the database manager must establish the access rights of individuals to the different data sets within the database. The database manager must ensure that proper protection against computer viruses are in place and updated regularly. Data sets are expensive and costly to replace. ESI-GIS, the GIS unit in Eskom, estimates the replacement value of its data sets at R60 million (De la Rey, 2006).
- Organisations change over time', so the acquired GIS and other systems and hardware must be flexible enough to incorporate new applications. New applications should be managed accordingly to ensure that they are of value to the whole organisation, and the same steps should be followed as for the initial implementation (Bernhardsen, 2002).
- Once the system has been acquired and the pilot project has started, the GIS and related systems and peripherals can be installed in the organisation. In Section 4.3.2.1.6 it is recommended that presentations should be made to inform the organisation of progress (Huxhold and Levinsohn, 1995). One managerial aspect of the presentations is the scheduling of the presentations to the relevant staff and departments to inform of progress. The next managerial aspect is the scheduling of demonstrations once the GIS has been installed using data from the organisation to demonstrate its capability and to obtain feedback on how to fine-tune the final implementation.
- The project manager has to manage the reporting of the project. During the acquisition and development of the GIS, the databases and peripherals, such as printers and plotters, the project manager needs to know the progress being made and whether the project is still on schedule. The management aspects could include the following: the different types of reports that must be written (i.e. executive needs an overview of the status of the project, possible problem areas as well as methods to

address these problems, whereas the project manager needs a detailed report on the various aspects of acquisition and development); frequency of reporting and managing the final consolidated report once the acquisition and development of the GIS have been completed and demonstrated.

Several managerial aspects regarding the acquisition and development of the GIS have been discussed above. During the presentation and demonstration of the GIS, some issues of functionality, data, etc. may have arisen and these will have to be addressed during the full implementation of the GIS in the organisation. The managerial aspects of the implementation are discussed in the next section.

4.3.2.8 Managing the implementation of the GIS

This phase investigates the different management aspects when implementing the GIS into the whole organisation, taking into account the recommendations made during the pilot phase. Huxhold and Levinsohn (1995:109) indicate the following outline that could be used in an implementation plan. This outline will guide the management of the implementation:

- The plan should have an introduction to the content and give an overall reason for the implementation of the GIS.
- The background section discusses the strategic vision of the organisation and how GIS will assist the organisation to achieve its vision, as well as what work has been done up to now, such as the selection of the implementation team, etc.
- The scope of the project as discussed in Section 4.3.2.1.2.
- A conceptual overview of how the GIS will support various business functions in various units of the organisation as well as the overall sequence of the implementation and development, indicating which business functions and units will be affected first.
- The management framework of the implementation process introduces the implementation team members and their respective roles and

responsibilities, the co-opting of user workgroups where necessary and their role within the whole process.

- An overview of the different tasks describing the major steps involved in each task.
- The implementation schedule using tools such as Gantt charts showing the different project phases and tasks.
- A detailed budget of the implementation process.
- Project administration tasks including contracting, purchasing, fund management, authority of project managers, standards, policies, reporting, etc.

The managerial aspects are addressed in the management framework which states who is responsible for which activity of the implementation process and the participants. If clearly defined tasks are managed effectively, this will instil confidence in executive and senior management that the GIS will be properly implemented and that productivity of the affected staff and project moral will be improved (Huxhold and Levinsohn, 1995).

Tools such as a Gantt chart to schedule the implementation tasks can assist in the overall implementation management. Tasks can run concurrently to improve the pace of implementation. These tools, together with frequent reporting on activities and progress, allow the management of each task such as the responsibilities, results, time frames, which sub-tasks can be done concurrently and which sub-tasks are a prerequisite for other sub-tasks or tasks. This approach allows the project manager to monitor the implementation and provides an early warning mechanism to alert him or her of possible implementation problems, so that appropriate steps can be taken to bring the implementation back on track (Huxhold and Levinsohn, 1995).

4.3.2.9 Managing the training of users and staff

Section 4.3.2.1.8 gives the three different classes of training needed when a GIS is implemented in an organisation, namely the education of the users, formal training and continuous training of staff using the GIS. Huxhold and Levinsohn

(1995:174) discuss several aspects that must be managed when training users and staff:

- Who needs to be trained? Examples of target groups are senior management, end users and GIS operators. Training can also be used as a public relations exercise as Farrant (2006) discovered when the implementation team gave short training courses on GIS to managers and city councillors.
- What should be included in the content of the training curriculum? The content will be governed by the target group being trained. City councillors do not need the intensive training of GIS operators.
- Who will do the training? Training can be done in-house or it can be outsourced.
- In what format will the training be conducted? This can be either in seminar format, short courses, workshops or even enrolment at the local university.
- When will the training commence during the implementation process? Here it is necessary to decide when in the implementation process the different target groups will be trained, what the interval of training will be and the duration of the training.

Table 4.2 gives an overview of a training programme and its target groups (Huxhold and Levinsohn, 1995). This can be used as a guide to manage the training of staff during and after the implementation of a GIS in an organisation. Although the training of staff has been discussed under implementation management, it can also be applied under the topic of operational management of the implemented GIS, since staff from senior management to operator level change and the new incumbents need to be trained. GIS software and related hardware change continuously, thus necessitating regular refresher courses for various target groups.

Table 4.2: Example of a management framework for training and educating staff

(from Huxhold and Levinsohn, 1995:175, Table 6.2)

Who	Topics	Purpose	Forum	When
Senior management	GIS orientation Implementation	Benefits and implications of GIS implementation	Half-day seminar (GIS demonstration)	At the start of GIS planning and implementation When the needs arises after implementation
Business unit managers	GIS orientation Implementation process GIS fundamentals and applications	Familiarisation Allocation of resources	In-house seminars Attending GIS conferences	At the start of GIS planning Prior to GIS implementation During implementation When the needs arises after implementation
Non-technical end-user training	GIS orientation Implementation process Applications limitations	Familiarisation Use of GIS applications Capabilities	GIS concepts course In-house seminar Vendor training during installation	At the start of GIS planning Prior to needs analysis When the need arises after implementation
Operations staff	GIS orientation Task and technology-specific training Legal and regulatory issues regarding spatial data	Task and technology competency skills for GIS operation	GIS concepts course Vendor training On-the-job-training during and after installation	Prior to needs analysis and functional specification of technology When the need arises after implementation
Systems staff	GIS orientation Analysis and design GIS development tools	GIS design techniques competency Software customisation	GIS concepts course Vendor training Systems course	Prior to analysis and design tasks Prior to system installation and testing When the need arises after implementation
Project team	GIS orientation GIS project design and management Legal and regulatory issues regarding spatial data	GIS concepts GIS management competency	GIS courses Mentoring programme facilitated by a GIS expert	Prior to project start Prior to GIS implementation When the need arises after implementation

The legal and regulatory issues regarding spatial data have been included in the training of GIS operators and project team target groups. Regulatory issues are those regulations that deal with the different standards as discussed in Section 3.4.5.3 in Chapter 3. The management of the legal aspects and regulatory issues regarding GIS are discussed in the next section.

4.3.2.10 Managing regulatory and legal issues around spatial information or data

The management of regulatory (standards) issues regarding spatial information or data can be seen as a three-fold management activity. The first management activity is the identification of the applicable standards for the organisation based on its spatial information or data needs. An example is that if an organisation only deals with vector data and is not involved with location-based services (LBS), the standards regarding imagery and gridded data (ISO 19121, ISO 19124, ISO 19129 and ISO 19130) and LBS (ISO 19132, ISO 19133 and ISO 19134) are not directly applicable, so the organisation does not need to spend time and resources to fully understand and implement the standards, although a general knowledge of these standards is recommended.

The second management activity is the training of staff to enable them to adhere to these standards, such as the metadata standard (ISO 19115 and the South African metadata standard SANS 1878) or SANS 1876, which deals with feature instance identification. These standards are discussed in more detail in Section 3.4.5.3 of Chapter 3. Staff training on standards can be incorporated in the training part of the implementation process as discussed in Section 4.3.2.9. Other standards that play a role in organisation are the ISO 9000 suite of standards, which regulate the quality control and the documentation of the different process.

The third management activity regarding regulatory issues is the enforcement of standards. An auditing mechanism must be put in place as must the scheduling of the audits. Audits are done by internal staff who have been trained to conduct the audits and by external accredited institutions. The results of the audits will determine whether the unit complies with the standards and keeps it accreditation (Wikipedia, 2006). The ISO 191xx and the GIS standards in South Africa focus on the interoperability of GIS and the movement of data between the different systems and not so much on the processes, which are guided by ISO 9000 as stated above. The Spatial Data Infrastructure Act (Act No. 54 of 2003) makes provision for the establishment of the Committee of Spatial Information which oversees the enforcement of compliance with the various standards by the various data custodians (Coetzee, 2006). Data custodians in accordance with the Act are discussed in Section 3.4.5.3 in Chapter 3.

Regulatory issues can be used as a management tool. Cassettari (1993) maintains that standards, if applied properly, assist with the correct development of the GIS and its implementation in an organisation. Another management application is the use of the ISO 191xx suite of standards and local national standards to ensure smooth data transfer between the different systems. These systems can be integrated as part of an organisation or partnering organisations, or they can be stand-alone systems with data being transferred between them (Cassettari, 1993).

The above paragraphs give an overview of the management of regulatory issues applicable to the creation of GIS products by an organisation. There are also legal aspects involved in the creation of GIS products, such as copyright and access to the data by affected parties especially, when dealing with environmental impact assessments. The next few paragraphs will explore the management of the legal aspects as discussed in Section 3.4.5.2 in Chapter 3 which have an impact on spatial information or data.

The Spatial Data Infrastructure Act (Act No. 54 of 2003) enforces the GIS unit or organisation to apply specific standards when creating or maintaining core data sets. The management of these has been discussed above. The Spatial Data Infrastructure Act has the following managerial impacts:

- It influences the management of GIS projects. The GIS unit or organisation has to ensure that it is not duplicating a core dataset and that it can prove that it made the necessary enquiries to establish whether such a core dataset exists or not.

- It influences the management of access to core data sets , either in-house or external. An example is the Municipal Demarcation Board which makes the core data sets of municipal and other related boundaries and related attribute data available for downloading from the Internet. Access is free and easy, but the person or institution downloading the data must register to enable the Municipal Demarcation Board to audit the downloads. The information captured through registration must be analysed, which is a management function on its own. Another management issue regarding access is to ensure that a disclaimer of liability of the supplier who makes the spatial information or data accessible is expressed in clear legal terms. The disclaimer by the Municipal Demarcation Board (MDB) is given as an example below in Table 4.3 (MDB, 2006b).
- It influences the management of copyright of the core data sets collected, especially those by the State. Managerial aspects regarding copyright are discussed in the next paragraph.

There are two management requirements regarding copyright, namely how to manage copyright infringements of spatial information and data that the GIS unit or organisation created, and how to manage copyrighted spatial data that the GIS receives from its suppliers. As explained in Section 3.4.5.2 in Chapter 3, the Copyright Act of South Africa provides protection of spatial information or data that have either been collected or value-added using existing data sets.

The GIS unit or organisation must have a management process in place to deal with copyright infringement of its own spatial information or data. The process must be able to deal with detection of an infringement, the legal process that the GIS unit or organisation has to go through, which may include the use of legal experts and possible court cases. The GIS unit or organisation may have to put in place measures to reduce infringements, and budget resources to deal with infringements.

Table 4.3: MDB disclaimer (from Municipal Demarcation Board, http//www.demarcation.org.za, downloaded on 13 November 2006)

Disclaimer
The Municipal Demarcation Board's website is provided to you as a tool "as is" to assist /provide you the user with relevant information as well as documents and statistics that are provided both by the Board and by various other stakeholders pertinent to the Boards work. While the Municipal Demarcation Board makes every effort to ensure that the contents of this website are accurate and complete, the Municipal Demarcation Board makes no representation or warranty, whether express or implied, as to the operation, integrity, availability or functionality of this website or as to the accuracy, completeness or reliability of any information on this website.
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With regard to the Spatial information the updatability and relevance should be verified by the Municipal Demarcation Board's helpdesk on info@demarcation.org.za or 012 342 2481.
The contents of any official notice or map on the website that was published in terms of any Act should be verified against the notice and/or map published in the Government Gazette or the relevant Provincial Gazette.
The contents of this website may be used for private, official or business purposes on condition that the source is acknowledged, and with the clear understanding that this disclaimer remains applicable.
The Municipal Demarcation Board does not accept any responsibility for any errors or omissions on this website.

The GIS unit or organisation must have management procedures to ensure that it does not infringe the copyright of spatial information or data that it receives from its suppliers. An example is to have a simple procedure in place to determine the copyright issues surrounding the specific spatial data set, and what the implications are when the unit adds value to the data and may copyright the value addition. The last managerial aspect regarding copyright is to manage the GIS unit or organisation when it is accused of infringing the copyright of supplied data. This includes how it will respond to such an accusation, the legal team that will be involved when it investigates where in the process of the creation of the GIS product the infringement took place, and dealing with any legal procedures.

The Legal Deposit Act of 1997 requires that data sets created by a GIS unit or organisation which is part of a state organisation, parastatal or other public registered organisation must be deposited at a designated place for safe keeping. The determination, of which data must be placed in safe keeping, and the scheduling of the transfer of the created or maintained spatial data to the designated place of safe keeping, must be managed.

The Promotion of Access to Information Act of 2000 stipulates the right of a person to have access to information held by the state or a private entity. The GIS unit or organisation must manage such requests by ensuring that there is a procedure and a designated person(s) to deal with requests and that the person(s) understands the Act to be able to respond correctly to the request, especially when access to the information is denied.

The South African Geographical Names Council Act of 1998 deals with the naming of geographical features as discussed in Section 3.4.5.2 in Chapter 3. The Act guides the GIS unit or organisation on managing adherence to the required standards, which links to the regulatory aspects discussed above and has an impact on management of the maintenance of spatial data when geographical names change.

The GIS unit or organisation may acquire spatial data with official statistics as part of the attribute data, and this may include confidential information on people and entities. The GIS unit or organisation must manage the confidentiality of this information as part of its GIS product creation management procedures. The GIS unit or organisation must manage the confidentiality of people and entities when they create GIS products which do not include official statistics. An example this is a project currently being done by the CSIR where locations of individuals are obtained on a periodical basis, such as every five minutes, using information obtained by active tracking. Due to the sensitivity of the data, which involves the subscriber number of the individual, the project team must manage the confidentiality issue by ensuring that the number is replaced by an identification number generated by a one-way hashing process, which makes it impossible to relate it back to the subscriber number. This allows the address and other locations linked to the particular individual to be determined. The research is also guided by an ethics committee from the University of Pretoria[4]. The managerial activity regarding ethical issues entails the creation and submission of the application to the ethics committee, including all relevant documentation and letters, and managing the recommendations and re-submission of the application if required by the ethics committee.

If the GIS unit or organisation sells spatial data through e-Commerce, the Electronic Communication and Transaction Act of 2002 gives guidelines on consumer rights and the protection of the consumer's information. The management aspects are to ensure that the GIS unit or organisation adheres to the legal requirements, that the e-Commerce site is a secure site and that critical databases are adequately protected.

According to Section 3.4.5.2 in Chapter 3, legal liabilities regarding GIS units or organisations must be managed as follows:

- The management of contractual liability is concerned with the management of the processes to be followed if a supplier reneges on his/her contract, such as the legal process, the contracting of legal experts and the costs involved. The other management aspect of contractual liability is the management of processes when the GIS unit or organisation is involved in breach of contract or reneging on warranties given to the client.
- The South Africa Spatial Data Infrastructure Act of 2003 states in Section 21 that "*no person is liable for anything done in good faith in the exercise or performance or purported exercise or performance of any power and duty in terms of this Act".* This means that if the GIS unit or organisation feels that a supplier is not in compliance with the Act, the GIS unit or organisation must prove non-compliance. The process involved in

[4] Generating and Harnessing of Dynamic Spatial Intelligence. An internally funded CSIR research project to investigate using locational information harnessed by actively tracking cellular telephones and applying the information to determine daily activity patterns and travel behaviour. The student is part of the project team.

proving non-compliance must be managed, such as determining the nature of the non-compliance, resources needed to prove non-compliance and the legal requirements and costs involved.

- Tort liability is creating false expectations, misleading and/or inaccurate spatial data, neglect and fraudulent misrepresentation. This must be managed when the GIS unit or organisation is accused of such liability by its suppliers. Management includes legal processes and resources and costs. Another aspect is the management of processes when the GIS unit or the organisation is liable for tort.

The management of legal and regulatory issues is important and these managerial aspects need to be taken into consideration when a GIS is implemented in an organisation. Non-compliance with legal and regulatory aspects can have dire consequences for a GIS unit, and if it is not aware of these requirements, it opens itself to expensive legal costs, which could lead to the demise of the GIS unit or the organisation in which the GIS has been implemented.

4.3.2.11 Conclusion

Huxhold and Levinsohn (1995) and Somers (1998) indicate that management is the most important activity when the implementation of GIS goes from the planning and design stage to the operational stage (transition). Somers (1998) also states that implementation management must ensure that the GIS is designed for the particular organisation's needs and not to be copied from another similar organisation. The processes that are managed are discussed above. Implementation management should be flexible as the implementation process can occur over a period of a few years in which the technology, the software, the organisation's needs and the response to need may change, which can then be incorporated in the implementation process (Somers, 1998).

Other implementation issues that have to be managed according to Huxhold and Levinsohn (1995), are the changes that the implementation will bring to the organisation, as indicated during the planning and designing phase of the implementation project.

Part of change management is to have a clearly defined implementation plan based on the final GIS, as discussed in Section 4.3.2.8. The plan incorporates assigning and training of resources; procurement management and the management of contracts and contract practices.

Huxhold and Levinsohn (1995) give the following three types of changes that must be managed during the transition from planned and developed GIS to operational GIS: the change in the final project plan with respect to the previous project plan, the organisational change that is required to facilitate the implementation of the operational GIS, and change that is the result of implementing the operational GIS in the organisation.

Well-facilitated change management ensures that enthusiasm for, and buy-in into, the GIS is maintained (Huxhold and Levinsohn, 1995). An example of change resulting from the implementation of a GIS in an organisation is the sharing of data across functional boundaries within the organisation. Successful change management is achieved by allowing staff to participate in the management and implementation process (Huxhold and Levinsohn, 1995 and Somers, 1998).

Staff problems will occur during change as job descriptions and operational procedures will be changed to enable the efficient and effective operation of the GIS. Huxhold and Levinsohn (1995:167) have identified the following seven procedures to minimise behavioural problems when implementing a GIS:

- Positive organisational climate to allow for change.
- Participation in discussions during the implementation process.
- Clearly defined characteristics and purpose of the GIS.
- Willingness to weigh individual needs against system efficiency.

- Emphasis on new and challenging jobs to replace those taken over by the GIS.
- Establishment of new criteria for performance evaluation.
- Tailoring of output to meet user's needs.

Staff training must be managed carefully to ensure that staff are trained correctly and timeously for the new tasks that they will be required to fulfil when the GIS is implemented (Huxhold and Levinsohn, 1995 and Korte, 2001). This section discussed the implementation of a GIS in the organisation from conception to implementation as an operational system. Once the implementation is completed and the GIS is operational, the management of the GIS changes from implementation management to operational management. The operational management of the GIS is discussed in the next section.

4.3.3 Operational management of GIS

Sugarbaker (1999) discusses the management of an operational GIS under the following headings of customer support, operations support, data management support, applications development and support, and project management. A GIS creates a product irrespective of whether it is an enterprise GIS, a departmental GIS or a stand-alone GIS project; and a product needs a customer, which can be internal or external to the organisation. Under customer support management, Sugarbaker (1999) discusses the issues surrounding order management, customer relations management and customer support in the form of training and helpdesk functions. Operations support deals with system administration and support, which can be outsourced to the organisation's information and technology (IT) department. Administration and support includes the maintenance of the IT infrastructure, hardware and software and security, back-up and acquisition functions. Operations support management should be included when the GIS is planned, developed and implemented to ensure that the correct support is given and managed (Sugarbaker, 1999 and Korte, 2001).

Section 4.3.2.1.6 discusses the implementation process, the creation and population of the databases, and the different types of data warehouses that can be developed to support the needs and functionality of the GIS. During the operational phase, database management support is required to manage the databases and/or data warehouses regarding the developing data standards, data quality, version control, metadata, designing storage based on the logical models developed (data organisation), access control, back-up schedules, data recovery as well as database and/or data warehouse upgrades, and the migration of the data (current and archived) to the new system (Sugarbaker, 1999; Korte, 2001 and Santi and Morgan, 2004). Access control is necessary, especially for spatial and non-spatial data that can impact on the privacy of individuals (Anonymous, 2001). The Statistics Act, 1999 (Act No. 6 of 1999) controls privacy issues in South Africa. Santi and Morgan (2004) suggest that full-time database/data warehouse managers should be employed in large organisations to manage and maintain data to enable the GIS staff to work on GIS-related projects.

With regard to very large spatial and non-spatial data management systems, it may not be possible to retrieve and deliver *all* the relevant data to create a specific GIS product required to solve a specific problem or to meet a specific need (Vert *et al.*, 2002a). To overcome this possibility, Vert *et al.* (2002a) propose the use of an entity relationship diagram (ERD) and combine it with fuzzy logic modelling. This will allow the extraction of related data sets using overlapping attributes based on metadata. The ERD model uses set management to extract related data files. A set is a collection of data sets, i.e. maps, imagery and non-spatial data, which are related to specific topics such as "Cholera outbreaks in KwaZulu-Natal". It is most probable that such a set may have similar data sets of various vintages or different data sets that have similar spatial coverage in a database or data warehouse that could be more relevant than others (Vert *et al.,* 2002a) depending on the need. For example, a person or organisation is interested in historical outbreaks of cholera in KwaZulu-Natal and thus needs "old" data sets, but as the Department of Health is only interested in the most recent outbreak it only needs the latest data available (Martin, 2004).

To enable the ERD model to deal with these differences and to help the user to select the correct data, Vert *et al.* (2002a) propose the use of fuzzy set theory.

This approach was used by Vert *et al.* (2002b) to manage the spatial and non-spatial data related to an area known as the Experimental Forest belonging to the University of Idaho, College of Natural Resources. These data sets are used by numerous students and must be managed appropriately to keep track of the changes made to the data, document the changes and allow the database manager to keep the data sets in a sound and incorruptible state (Vert *et al.,* 2002b).

Another aspect of operational management is the management of the creation of new applications since the organisation's business needs and the software change over time. Management includes the setting of development standards and conventions, adherence to the standards and the proper documentation of the applications developed. Change management is necessary when implementing the new applications. The maintenance and support of existing applications must be managed to ensure the efficient and effective functioning of the implemented GIS (Sugarbaker, 1999).

Projects create GIS products and must thus be managed properly to enable the GIS in the organisation to deliver the right product at the right time to the right customer. Project management can be done by the GIS manager who assigns staff to different projects and monitors the progress, or qualified project managers can be employed who manage resources, staff, budgets and the different projects (Sugarbaker, 1999). Project managers are also responsible for workload planning, or if the GIS manager does the workload planning, the project managers should be part of the planning process, as well as being responsible for budgets or participating when budgets are drawn up by the GIS manager (Sugarbaker, 1999).

Huxhold and Levinsohn (1995) regard GIS and related personnel management as part of the management of an operational GIS. Personnel management includes the training of personnel as well as recruitment. When the organisation decides to implement a GIS, it should or will function for at least several years, during which time hardware, software and data have to be maintained.

The management of resources is another aspect of managing an operational GIS. The management functions include the management of GIS licences, stand-alone and networked licences, hardware such as plotters and printers and the acquisition of new or additional GIS and upgrades (Nielsen, 2005). Upgrades ensure that the organisation has the latest version of their GIS. The organisation has to pay an annual maintenance fee to the vendor. GIS licence management includes setting up and maintaining the licence in conjunction with the organisation's information technology department and determining which staff member has access to which licence (Nielsen, 2005). The management of hardware such as plotters and printers comprises the acquisition of ink and paper, the scheduling of maintenance of the hardware as well as the replacement and/or acquisition of new hardware (Nielsen, 2005). Acquisition of additional or new GIS software management includes the acquisition process and scheduling the implementation of the new or upgraded software (Nielsen, 2005).

The last managerial aspect under operational management to be discussed is the management of a long-term GIS. A long-term GIS is defined by Chan and Williamson (2000) as a GIS that has been implemented for 15 years or more and has undergone several restructuring exercises, or a GIS with an expected life cycle of 15 years or more that is being implemented in an organisation.

Over this time period, departments with GIS functionalities may amalgamate or disaggregate into several new units. There may also be a change in leadership at line function level as well as at senior management and executive level. These changes impact on the use, growth and support of the different GISs that are implemented (Chan and Williamson, 2000). Chan and Williamson (2000) propose the following management framework to manage a long-term GIS:

- The first stage is management of the implementation of the initial GIS to ensure proper implementation as discussed in Section 4.3.4. Chan and Williamson (2000) call this the business GIS, the GIS that creates the products to fulfil the needs of the organisation and ensures buy-in of all the stakeholders.

- The second stage is to entrench the use of an enterprise-wide GIS, which includes the management of resources as discussed above. The entrenchment of an enterprise-wide GIS lays the foundation for guiding GIS development in the future.
- The last stage is the encouragement of further development of the GIS based on one of the following three approaches: "*systematic, opportunistic-business process or opportunistic infrastructure*" (Chan and Williamson, 2000:302). The systematic approach is a well structured and planned implementation of a GIS similar to the implementation process discussed in Section 4.3.2.1. The opportunistic-business GIS implementation process is where a GIS is implemented by a business unit or units that utilises minimum resources with no support of senior management or executive to fulfil the unit's or units' business needs. It is also used as a kind of technology demonstrator, and the use of this type of GIS grows as other business units realise its potential. The opportunistic infrastructure process is the implementation of an infrastructure GIS, which according to Chan and Williamson (2000) is a GIS that supports the business GIS. An example would be an infrastructure GIS that creates core or base data sets and the business GIS then utilises these data sets to create GIS products that fulfil a specific unit's business needs. The opportunistic-infrastructure GIS implementation follows the same process as the opportunistic-business GIS implementation.

The operational management of an implemented GIS includes the day-to-day operations of the GIS, resource management and the long-term management of the GIS to ensure its long-term operation. The resource management of a GIS was discussed briefly along with the maintenance aspects of GIS software and hardware. These as well as other maintenance management aspects will be examined in more detail next.

4.3.4 Maintenance management of GIS

The maintenance management of a GIS concerns the managerial aspects of maintaining the software, the hardware (as discussed briefly under resource management in the previous section) and, most important to the organisation, the maintenance of spatial and non-spatial data (Huxhold and Levinsohn, 1995 and Korte, 2001). The GIS software that was procured based on the implementation process changes over the years. The developers release new versions of the software with improved and added functionality on a regular basis (Huxhold and Levinsohn, 1995 and Nielsen, 2005). To enable the organisation to improve its GIS capability and to fulfil its changing needs, the organisation has to manage the maintenance of the GIS and acquire the new versions. A common management practice is to enter into a maintenance agreement with the vendor, which for a specified cost will enable the organisation to receive regular upgrades of the GIS software. In smaller organisations, the maintenance management is incorporated into the operational management of the GIS. When the budget is developed for the GIS implementation, maintenance costs should be factored in (Huxhold and Levinsohn, 1995).

The maintenance of hardware can be grouped into two categories, namely the maintenance of the existing hardware, such as support of the hardware, and the replacement cycle of the hardware. Hardware, as with software, is improved over time - faster processors, bigger storage capabilities, etc., and the hardware that was procured when the GIS was implemented will become obsolete over time and will need to be replaced (Huxhold and Levinsohn, 1995). Depending on the type of hardware, a replacement and migration cycle can be planned. Servers that house the databases and/or data warehouse may have to be upgraded every three years, thus the management involves establishing the cycle and making provision for the smooth change-over and migration of the data. One important aspect is also the migration of archived data, so that the archived data can be read by the new hardware. Plotters may have a replacement cycle of five years or more depending on their use.

The most important maintenance management function of a GIS in an organisation is the maintenance of spatial and non-spatial data. Korte (2001) states that data editing is an activity that needs to be managed carefully. If a single person is responsible for data editing, maintenance management is straightforward as that person is responsible for ensuring that the currency of the data is valid. Maintenance management can become more complex and Korte (2001) proposes the following two approaches where multiple editors access a GIS data server:

- The first method is to lock editing at a file level, which means that only one person at a time has editing rights on a specific file. Other people can use the data, but cannot make any changes to it.
- The second method is to feature lock the editing, where a person can only edit the selected feature. This allows multiple editing by several editors but only an editor is allowed to edit a specific feature. Figure 4.7 illustrates these two methods.

Part of data maintenance management is to ensure that the associated metadata are updated as the data are being maintained.

This section examined the three basic management issues in GIS, namely implementation, operations and maintenance management to give an understanding of current management practices with regard to GIS. These three basic management issues involve the management of a GIS at an organisational level, which is either at an enterprise or departmental level, but not at the production level. The next section discusses management at project level and examines workflow as a management tool to assist during the production of spatial and related non-spatial data.

4.4 Workflow

Koulopoulos (1994) says that documents that are produced in an office environment can be connected to form a value chain that can reach beyond the office or even beyond the organisation, and that workflow can be used to eliminate unnecessary tasks. These results in a saving of cost and effort to create the documents, and certain parts of the document creation process can be automated to improve the cost and effort saving and even further.

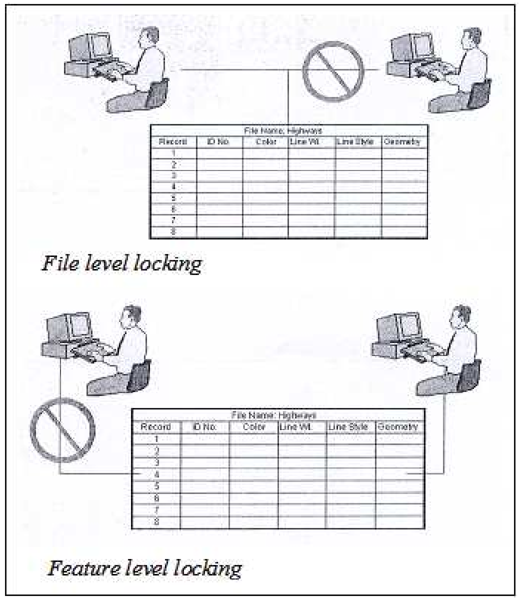

Figure 4.7: File and feature level locking methods for editing data in a GIS data server

(from Korte, 2001, p 191)

Workflow according to the Workflow Management Coalition (WfMC, 1998 as quoted in Li and Coleman, 2004:4) is defined as "*the automation of business processes during which documents and tasks are passed among participants according to a set of procedural rules and assigned roles*". Business processes according to the WfMC are those linked sets of procedures and activities that are put in place to achieve the organisation's strategic objectives (Li and Coleman, 2004). Thus workflow enables the organisation to capture information, processes and rules that are used to create documents and data with the aim of eliminating and/or reducing redundancies and time, and determining which part of the process can be automated (Koulopoulos, 1994). Koulopoulos (1994) sees the office as a document factory which must be managed by adapting factory automation disciplines such as Total Quality Management (TQM), Electronic Data Interchange (EDI) and Just-in-Time (JIT) methodologies.

These methodologies are discussed in detail in Chapter 2, where it is explained that they are used to improve the supply chain activities. Traditionally an information system is used to generate documents and information, which are recreated and changed for every task or process, even if the task or process is repeated several times, whereas workflow re-engineers the information system, not only to generate documents and information, but also to have all the necessary documents and information at hand to support each task or process (Koulopoulos, 1994). Li and Coleman (2004:2) state that workflows have proven themselves over the years as an enabling technology to "*improve productivity and process efficiency by facilitating, automating or controlling business processes"*.

Workflows are managed by the Workflow Management System, which automates the procedures of a specific business by managing the sequence of the different work activities required, as well as triggering the inputs from associated human and/or information technology resources at the appropriate stages of the process (WfMC, 1995). The basic characteristics of a Workflow Management System according to WfMC (1995:7) as illustrated in Figure 4.8 are:

- *"The built-time functions, concerned with defining, and possibly modelling, the workflow process and constituent activities."* Built-time functions are used to translate the business process into a process definition, also known as a process model. The process definition consists of a number of activity steps that are associated with specific human and computer operations, as well as the rules governing the business process as it progresses through each activity step.
- *"The run-time control functions are concerned with managing the workflow processes in an operational environment and sequencing the various activities to be handled as part of each process*." The control function is the Workflow Enactment Service that creates and controls the different operations or tasks of the process at the scheduled steps, invoking appropriate human and IT resources.
- *"The run-time interactions with human users and IT application tools for processing the various activity steps*." The Workflow Enactment Service triggers human interactions, which could be entirely manual or with IT support, or triggers different software applications to create information at the appropriate step in the process. The service also passes data from a

database or data warehouse to the different actions when required. Human users and the IT application tools are known as *agents*.

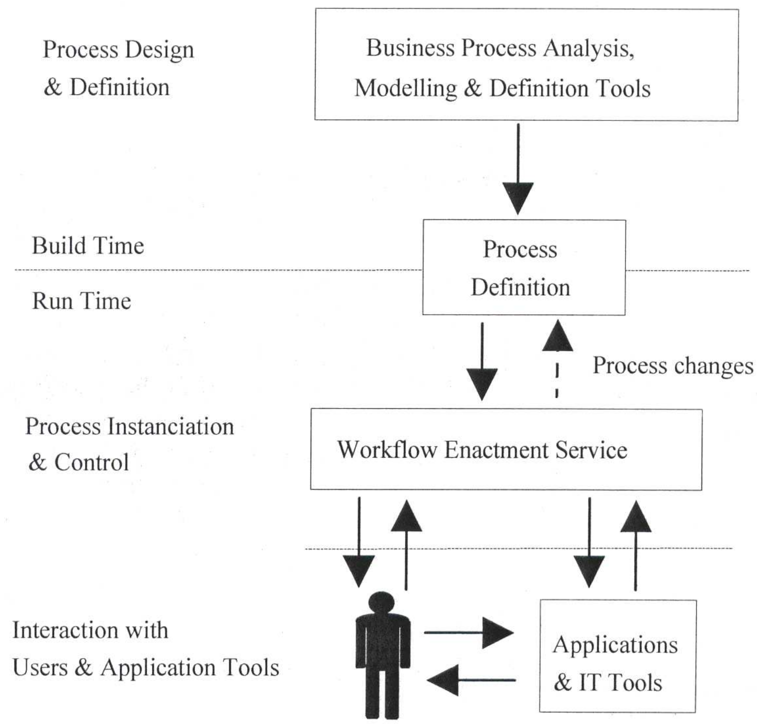

Figure 4.8: **Workflow system characteristics**
(from WfMC, 1995:7, Figure 1)

WfMC (1995) indicates that the workflow run-time infrastructure has the ability to distribute tasks, which can operate on a variety of levels such as workgroup-to-workgroup or workgroup-to-inter-organisation using various forms of technology, such as e-mail, the Internet, LAN and distributed object technology. Built-time and run-time are also known as modelling and execution respectively (Seffino *et al.,* 1999). Figure 4.9 shows the basic components of a workflow structure.

The above paragraphs have discussed workflow in a business context. For the scientific context workflow has been adapted to "*document and control the execution of scientific experiments"* (Seffino *et al.,* 1999:108). Scientific workflow is used in procedures such as DNA sequencing (Seffino *et al.,* 1999). Seffino *et al.* (1999) explain that scientific workflows differ from business workflows in that scientific workflow is experiment oriented, that scientific workflow modelling allows for the trial-and-error and "ad hocness" of scientific experimentation and that it is flexible to allow on-the-fly specification of the experiment (in workflow terms a case), which is not the norm with traditional business workflows

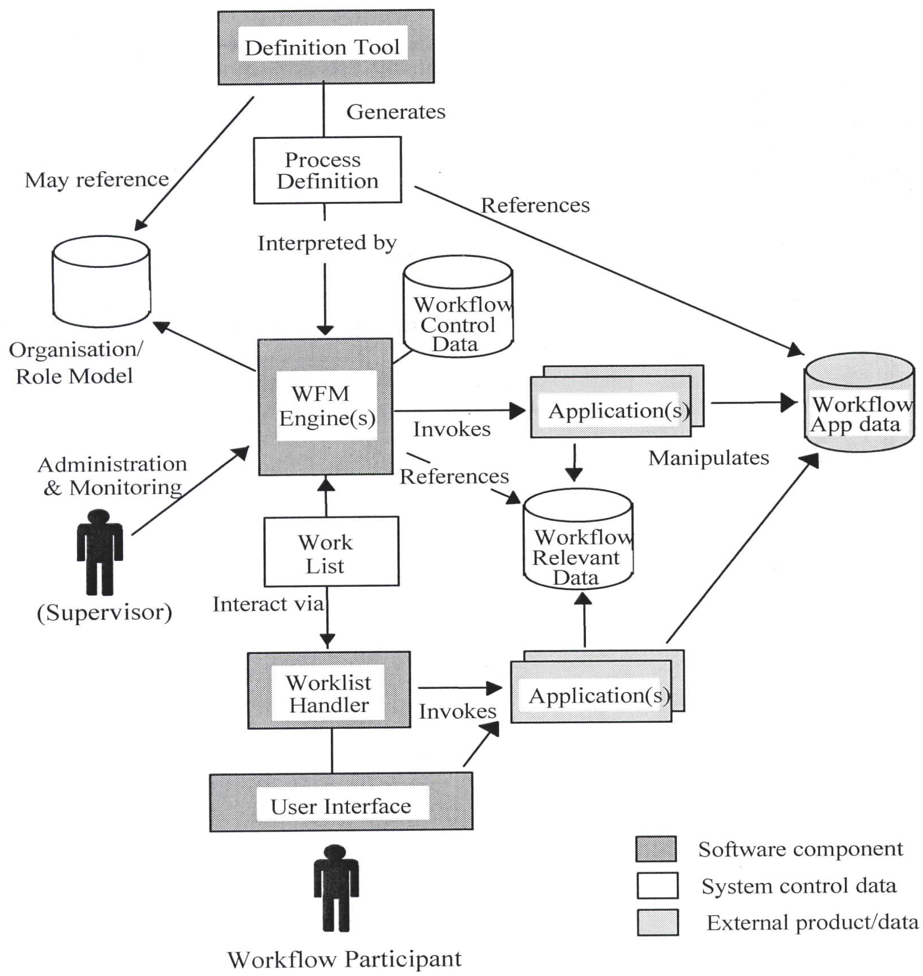

Figure 4.9: Basic components of a workflow structure

(from WfMC, 1999:39, Figure 5)

Scientific workflows allow the documentation of experimental failures and the corrected experimental process that was successful (Seffino *et al.,* 1999). Seffino *et al.* (1999) enumerate the following additional main aspects of scientific workflow compared to traditional business workflows:

- “Ad hocness” and incompleteness allows incompletely designed workflows, which are completed during the execution of the experiment, whereas business workflows must be complete before being implemented.
- Existing workflows can be partially re-used to create new workflows to specify experimentation.

- Scientific workflows, when in progress, can be abandoned due to the results of an experiment that indicate failure, can later be rewound (backtracked), e.g. to establish where the error occurred. A new workflow specification can then be created on the fly from the point in the process or experiment where the error occurred.
- Scientific workflows allow tracing of invalid processes, thus documenting faulty processes, which can be used to correct mistakes. Scientific workflows allow documentation of failed processes as well as successful processes.
- In the business workflow the workflow specifies the execution (case), and in the scientific workflow the case specifies the workflow (Seffino *et al.,* 1999).

There are two examples where workflow is used in a GIS, namely a spatial decision-support system that uses a scientific workflow (Seffino *et al.,* 1999), and workflow is used in GIS data production (Li and Coleman, 2004). These two examples are discussed briefly below.

Seffino *et al.* (1999) developed a spatial decision-support system using workflows, known as WOrkflOw-based spatial Decision Support System (WOODSS). This software can be linked to a commercial GIS to aid in the decision-making processes in agri-environmental planning activities. As mentioned above, the workflow used in WOODSS is the scientific workflow. WOODSS has three main goals (Seffino *et al.,* 1999):

- Documentation, which captures the decision-makers' interaction with the GIS in the form of scientific workflows and is stored in WorkflowBase, a database developed for this purpose. WorkflowBase acts as a storage facility and a clearing house for previous workflows, which can be used to develop new workflows using similar data or even to repeat the decision-making process with the same data, but from a different geographical area.

- Support for decision-making by WOODSS, which provides not only a documentation facility as discussed above, but also the executable specifications required for the different activities in the decision-making process. WOODSS, since it is based on scientific workflows, allows updating on the fly, the re-use of partial workflows to feed into larger decision-making processes and validation of the processes.
- Model base construction. A spatial decision-support system uses several spatial analysis models and other models if the need arises. These models form part of the decision-making process and WOODSS stores the models that were used in Modelbase, which can be retrieved by WOODSS when a new decision-support is run using the workflow part of WOODSS. The different decision techniques employed by the decision-maker is also captured in Modelbase. Figure 4.10 gives a schematic diagram of WOODSS from the decision-support perspective.

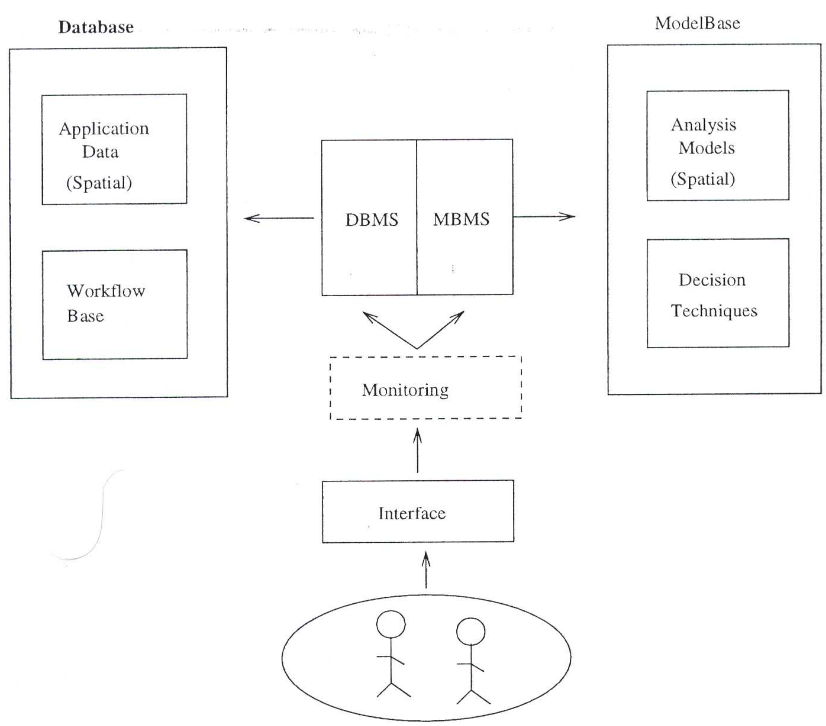

Figure 4.10: WOODSS from a decision-support perspective

(from Seffino *et al.,* 1999:111, Figure 1)

The architecture of WOODSS consists of the following modules (Seffino *et al.*, 1999):

- The interface through which the user interacts with WOODSS either by filling in predefined queries, which draws the information from WorkflowBase, or by changing the workflow elements using the interface's click-and-drag capabilities.
- The monitor captures the user's interaction with the GIS during a spatial decision-support session and translates these interactions as a workflow and stores them in WorkflowBase.
- The update module allows the creation of new workflows as well as modification and removal of existing workflows. The workflows can be changed by modifying different components or can be created by combining several existing workflows.
- The query module allows navigation and querying of WorkflowBase for existing workflows.
- Workflow Manager manages the workflows by existing workflows being extracted from the query module of WorkflowBase. Workflow Manager manages the workflows that are created using either the monitor or the update module.

WOODSS allows for three types of interaction: the direct use of the GIS by the decision-maker where WOODSS captures the execution using the monitor module, the direct use of WOODSS using the query/update modules, and a combination of WOODSS and the direct use of the GIS. WOODSS will monitor the latter activity to create and store the new workflows that are generated during the interaction (Seffino e*t al.,* 1999). Figure 4.11 gives an overview of the WOODSS architecture.

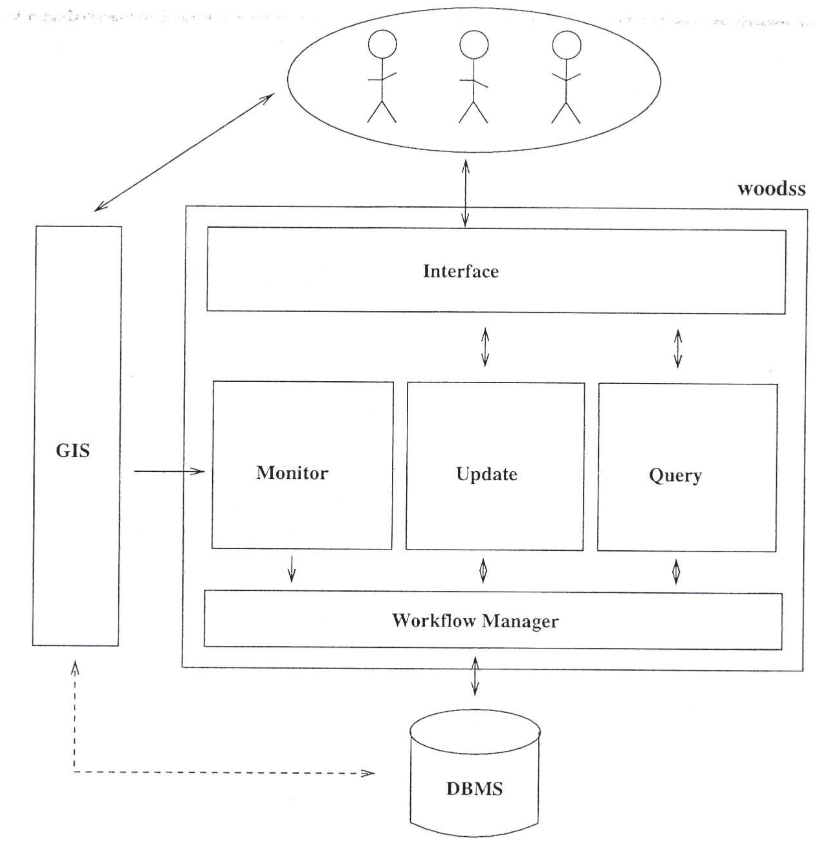

Figure 4.11: WOODSS architecture

(from Seffino *et al.,* 1999:112, Figure 2)

WOODSS was developed according to Seffino *et al.* (1999) to capture decision processes used by decision-makers when using a GIS in agri-environmental planning, but also to gather knowledge (workflows and models in the database) for future use. By using existing workflows and models it can automate specific decision-making processes.

The second example of the use of workflows is the research done by Li and Coleman (2004). These authors applied workflow to enable and monitor distributed GIS data production projects using workflow technologies that use the Internet, with the specific aim of improving data quality control of the GIS data produced. The distributed GIS data production is done on dispersed geographical areas (Li and Coleman, 2004). Li and Coleman (2004) modelled GIS production workflows by thoroughly examining all the resources involved, their related structural behaviours, such as standards and business rules, and the environments in which they operate in current GIS data production practices. Figure 4.12 shows the different input sources to model collaborative GIS data production workflows (Li and Coleman, 2004:9).

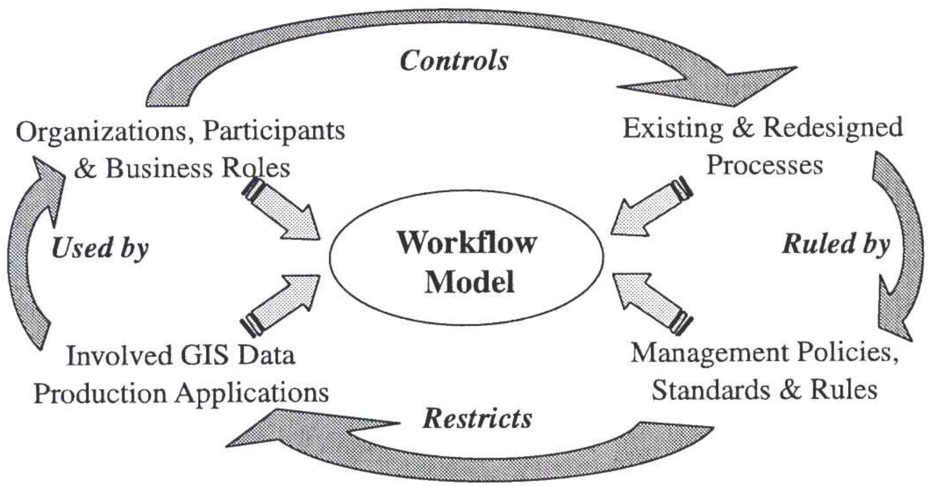

Figure 4.12: Workflow model inputs

(from Li and Coleman, 2004:9, Figure 3)

To enable workflow to manage distributed GIS data production, a workflow process repository was developed in which different process categories are stored. Each category consists of a process which has resources, such as input and output data sets, documents and other information objects, business goal(s) that describe the objectives to be achieved through this process, and activities that describe the GIS data creation processes and practices. In a workflow, the latter are the different GIS applications that will be linked or invoked during process execution (Li and Coleman, 2004). Process categories could be operation management, which could include data delivery management, data quality management and data production management; project management such progress tracking and project reporting processes; and information management such as project documentation processes and project issues related to management (LI and Coleman, 2004).

The components of the workflow model developed by Li and Coleman (2004:11-8) are as follows:

- Workflow process determination such as GIS data quality inspection, which is equivalent to WfMC (1995) built-time phase or modelling of workflow (Seffino *et al.,* 1999).
- Organisational structure, e.g. contract production structure (Figure 4.13) and task scheduling using scheduling methods such as *round robin, workload distribution* or *manual assignment* (Chang and Jaeckel, 2000, as referenced in Li and Coleman, 2004).

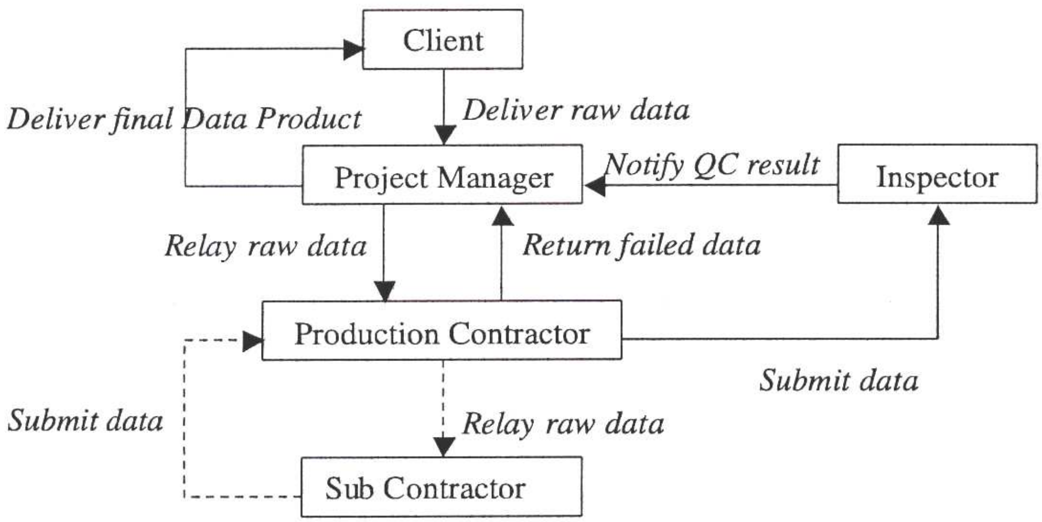

Figure 4.13: Contract production structure

(from Li and Coleman 2004:15, Figure 8)

- Invoked applications – there are two types of invoked applications, namely manual applications where workflow signals such an application and makes the required information available to execute the application, and automated applications that are invoked by workflow to run automatically, such as automatic quality control testing programs. Figure 4.14 illustrates the coordination of the workflow system and GIS applications.

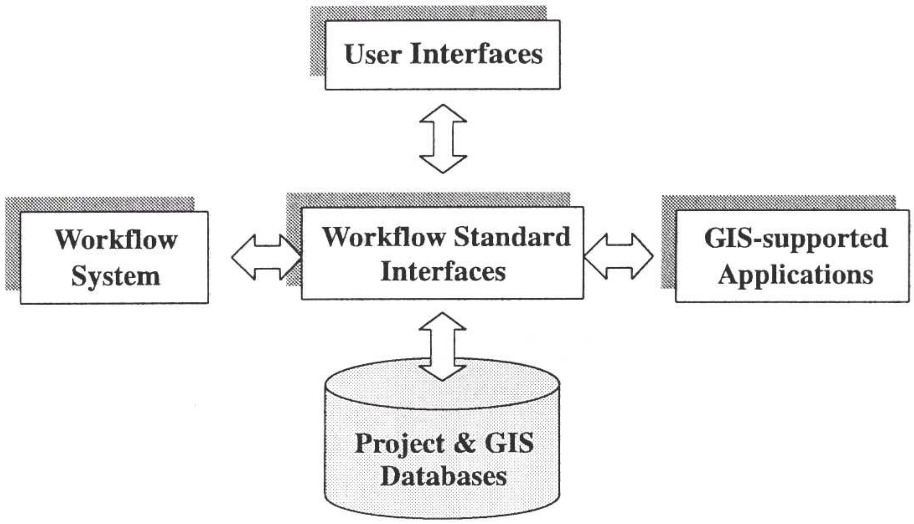

Figure 4.14: Coordination of the workflow system and GIS applications
(from Li and Coleman, 2004, Figure 9)

- A workflow data model, which consists of workflow application data (different applications that must be invoked at the required steps within a specific process), and workflow-relevant data such as shipment data, contract information, delivery date information and the latest version of a specific GIS data product.

Li and Coleman (2004) used the Oracle Workflow system to handle the distributed GIS data production in the form of a prototype to test whether workflows can be used to execute GIS quality control processes involving geographically distributed GIS data production organisations. Li and Coleman (2004) recommend that workflows be used in decision-making processes such as those discussed by Seffino *et al.* (1999) and to automate the updating processes of spatial data warehouses.

This section examined a management process at the GIS application level (spatial decision-support system and data production) using workflows. Workflows and implementation, operations and maintenance management are used where GIS will be used in organisation for several years. The next section investigates the management of GIS of a once-off or special project basis.

4.5 Management of special projects

Although once-off or special GIS projects are not included in the scope of this PhD research, it is worthwhile briefly to discuss the management of such projects. These projects have specific start and end dates, and after the end date the staff and resources are applied elsewhere. These projects are managed using traditional project management practices (Somers, 1998 and Sugarbaker, 1999). An example of such a project is the Australian datum change (Foley, 2004).

Australia changed its national datum from the Australian Geodetic Datum (AGD) to the Geocentric Datum of Australia (GDA) to ensure compatibility with satellite navigation systems, and to establish a single reference frame for all users ranging from local to international users. It will be the frame of reference on which the Australian Spatial Data Infrastructure will be based, and will create an infrastructure to support international agreements (Foley, 2004). The effect of the datum change from AGD to GDA on coordinate values created with the AGD datum will result in a 200 m shift of the mapped location if the GDA datum is used without transforming the coordinate values to the new datum (Foley, 2004). This special GIS project by Hydro Tasmania has two objectives, namely to transform all existing spatial data from the AGD to the GDA datum to keep the confidence in spatially related decisions based on the data, and to minimise the risk of using the coordinate values with the wrong datum when handling and exchanging spatial data, which could result in a displacement of 200 m of the location in question (Foley, 2004).

This special project consists of four phases (Foley, 2004). Phases 1 to 3 have been completed. Phase 4 is an ongoing process until the migration of spatial data from AGD to GDA has been completed:

- Phase 1: A GDA awareness campaign to inform employees of the impact of the datum change on existing and future projects, and a spatial data audit conducted to determine the volume and nature of spatial data.
- Phase 2: Analysis of the results of the spatial data audit. This has been translated into a determination of the level of business risk to the organisation. The action based on the results and the risks of addressing the datum change have been formulated.
- Phase 3: Methods have been developed to minimise business risk associated with the datum change, including the development of a Project Spatial Datum Toolkit to assist personnel to avoid datum misidentification.
- Phase 4: Monitoring of the risk-reduction measures implemented, recording of datum-related incidents and the development of new risk-reduction measures if required.

Sections 4.3 to 4.5 discussed different ways of managing GIS, ranging from managing a GIS implementation to managing special or once-of GIS projects. The next section investigates the reasons for a GIS to fail.

4.6 GIS failures

The above sections discussed the management of a GIS from various perspectives such as implementation management, operations management and the management of special or once-off projects. This section investigates why these can fail, even if the GIS has been implemented in an organisation.

Birks *et al.* (2003) discuss the failure of GIS within the retail industry in the United Kingdom using the high-performance equation developed by Schemerhorn in 1984. The Schemerhorn high-performance equation is (Birks *et al.*, 2003:75):

Performance = Ability x Effort x Support

All three factors must be present to ensure high performance (Birks *et al.*, 2003). Birks *et al.* (2003) base the reasons for the failure of a GIS on the three factors of lack of ability, effort and support:

Lack of ability:

- Overstatement of what the GIS is capable of, which leads to unrealistic expectations which cannot be met owing to the technical limitations of the implemented GIS (Korte, 2001).
- The implementation of the GIS and the related implications are more complex than anticipated, which leads to cost overruns, frustration and failure (Huxhold and Levinsohn, 1995).
- Downplaying of cost and personnel implications when the GIS is implemented in the organisation (Korte, 2001). This is done according to Korte (2001) to overcome the fear that senior management will not consider the implementation of a GIS.
- Disruptions of existing procedures and practices due to improper planning and enforcement of using the GIS, which is not properly designed to fulfil the users' needs (Huxhold and Levinsohn, 1995).
- Weak project management (Birks *et al.,* 2003).
- Lack of expertise and/or experience (Birks *et al,.* 2003).
- Failure to specify user requirements and data needs for the GIS or using the wrong assumptions, which leads to the wrong GIS being implemented (Huxhold and Levinsohn, 1995 and Korte, 2001).
- A GIS can be successfully implemented based on the current organisational set-up, but organisations change over time and if there is no long-term plan to enable the GIS to change (which can include expansion or modification of the GIS) so as to address the changing needs of the organisation, it can fail owing to its inability to support the changed organisation (Korte, 2001).
- Weak database management and the inability to deal with incompatible data sets (Birks *et al.,* 2003).

Lack of effort:

- The use of GIS as just an experiment to establish whether it may or may not work. This approach according to Korte (2001) leads to a lack of support, personnel, funding and priority in an organisation and is a recipe for failure.
- The lack of direction due to ill-defined or absent goals to align the GIS with the organisation's overall goals and objectives. This also leads to the absence of any criteria against which the achievements of the implementation can be measured (Huxhold and Levinsohn, 1995 and Korte, 2001).
- Weakly defined scope of the GIS implementation project or misunderstanding of the scope by the possible users of the GIS (Huxhold and Levinsohn, 1995).
- The top-down enforcement of using the GIS, although it may have been properly designed and implemented to fulfil the needs of the organisation, can lead to resistance to its (Huxhold and Levinsohn, 1995). This indicates a lack of effort to allow participatory implementation of the GIS.
- The GIS is only used to computerise current problems and processes, and it is not taken into account what else the GIS can do for the organisation (Korte, 2001).
- The continuous use of manual systems that should be handled by the GIS once it is operating properly (Korte, 2001). This translates into a lack of effort to learn the new system.
- Lack of user training of the GIS, which leads to the users being frustrated by their inability use it. This can result in the abandonment of the GIS by the users (Huxhold and Levinsohn, 1995 and Korte, 2001).
- Lack of reporting or failure to report the results of the GIS implementation and the results of using the GIS can lead to the loss of top management support, user enthusiasm and cooperation (Huxhold and Levinsohn, 1995; Somers, 1998; Korte, 2001 and Birks *et al.,* 2003).

Lack of support:

- Unstable organisational environment caused by regular change of ownership of the organisation leads to constant changes of top management (Huxhold and Levinsohn, 1995 and Birks *et al.,* 2003).
- Lack of customisation of the GIS to fulfil organisational needs. Commercial off-the-shelf GISs are designed to support a wide range of users, which can fulfil most of the needs of an organisation. To fulfil the needs that are not covered by commercial off-the-shelf GISs, the GIS must be customised according to user inputs (Korte, 2001).
- The lack or the abandonment of support from top management for the implementation of the GIS in the organisation (Huxhold and Levinsohn, 1995; Korte, 2001 and Birks *et al.* 2003).
- Lack of user involvement during planning, including user needs analysis, selection, development and implementation phases of the GIS, which could lead to resistance to implementing and using the GIS (Korte, 2001 and Birks *et al.* 2003).
- *"Passive forms of leadership can also cause a lack of cohesiveness and satisfaction"* (Birks *et al.,* 2003:76).

4.7 Conclusions

To give an understanding of the management issues regarding GIS, it was necessary first to provide a detailed overview of what a GIS is and that it can be used in a variety of applications as discussed in Chapter 3. From the discussion in Chapter 3 it was concluded that a GIS is complex by nature and must be managed properly to ensure its success within an organisation. Chapter 2 explored supply chains and supply chain management to provide the background to this research, and also to provide a yardstick to establish to what degree aspects of supply chain management are currently being used in the different management activities as discussed in this chapter.

This chapter discussed the different management aspects of a GIS, starting with the management of the implementation of the GIS. To give an understanding of implementation management it was necessary to discuss the different implementation phases in some detail, starting with the establishment of the implementation team that will manage and implement the GIS in the organisation, including the different roles that the team members have to play during the implementation stage, and ending with the physical implementation of the GIS in the organisation.

Operational management concerns customer support; operations support; data management support; applications development and support; and project management to ensure the smooth running of the implemented GIS.

Maintenance management is necessary for software and hardware upgrades, as well as the maintenance of spatial and non-spatial data used by the GIS in the organisation.

At the production level the management of the data creation process is discussed using workflows. Workflows are used to model the production process and to establish which parts can be automated and to develop triggers to activate manual and automatic activities at the appropriate step in the process and to make data and information available to enable these activities to be carried out.

The last maintenance aspect of a GIS is the maintenance of special or once-off GIS projects, which are managed using standard project management procedures.

The last section of this chapter discussed possible reasons for the failure of a GIS, whether during implementation or after it has been implemented using the factors in the high performance equation, namely ability, effort and support.

Implementation management is necessary to establish the GIS within the organisation, and it can link with the PLAN process of the Supply-Chain Operations Reference (SCOR) model from the Supply-Chain Council. A detailed overview of the SCOR model is given in Section 2.5.2 of Chapter 2. The availability of resources is important to the supply chain for its ability to create and deliver the GIS products required by the clients. Implementation management can ensure that these resources exist at the start of the production process. Maintenance management ensures that resources stay current to improve the supply chain performance. PLAN uses this information to balance the supply chain resources with the supply chain requirements.

Sections 4.3.3 and 4.3.4 discussed the operational and maintenance management of a GIS and GIS data, but the different management aspects of the operational GIS and the maintenance management of spatial data and related non-spatial data are discussed as disjointed elements in the whole process, which have elements of supply chain management as discussed in Chapter 2. Customers are treated as a separate entity by Sugarbaker (1999) and not as part of a supply chain, namely the DELIVER process of SCOR, although he does address certain parts under the heading of customer support such as order management, customer relations management and support.

Operations support management can be seen in the supply chain management context to support the resources required to create the GIS product (MAKE) part of the supply chain. Database and data management support as discussed in Section 4.3.3, especially with regard to standards and the different government acts, is similar to the ENABLE part of the SCOR model. ENABLE is discussed briefly in Section 2.5.2.1 of Chapter 2. Project management, which is discussed as part of operations management, can be used together with workflows (Section 4.4) to manage the physical GIS product creation part of MAKE of the supply chain. Workflows can be used to automate the complete product creation or parts of it as discussed in Section 4.4.

From the above it can be seen that only a small part of supply chain management is discussed in current GIS literature. These management processes seem to be executed in a silo fashion with little interaction between each management process. It is therefore suggested that, as concluded in Section 3.6, to enable an integrated management approach to the production of GIS products, **supply chain management** should be used.

It was therefore established that GIS units need effective management to perform well. It was also determined in this chapter that the management of GIS can be grouped into four groups, namely implementation, operations, maintenance and special projects. Operations management received some attention, but it was mostly attempted in a silo fashion as mentioned above. This does not provide a single management tool which integrates all aspects, and can lead to management problems. Supply chain management was identified as a tool that could solve this problem, and it will now be investigated whether supply chain management can be used for GIS units using the SCOR model as a tool to analyse and discuss the GIS supply chain.

Chapter 5: The application of supply chains and supply chain management within the GIS environment

5.1 Introduction

Chapter 2 gave an overview of supply chains and supply chain management as well as a definition of a supply chain for the purpose of this research, namely:

> *The supply chain is the movement and value addition of materials from suppliers to the manufacturer then to the customer as well as the activities associated with the movement and value addition of the materials up and down the chain.*

The definition of supply chain management for the purposes of this research was defined in Chapter 2 as follows:

> *Supply chain management (SCM) is the integration of these activities through improved supply chain relationships to achieve a sustainable competitive advantage (Handfield and Nichols, 1999: 2).*

Chapter 3 discussed Geographic Information Systems (GIS) with regard to their development over time, and different definitions of a GIS. The following definition was used:

> *A GIS is a computer-assisted system, combined with appropriate infrastructures, resources and management, that acquires, stores, retrieves, transforms, manipulates and displays geographical and related non-geographical data.*

The principles of GIS were discussed which encompass the nature of spatial data, how geographical data are represented in the computer environment, the various functional issues of a GIS, the displaying of the spatial environment in a

GIS, as well as the different operational issues involved in a GIS which range from the implementation of a GIS in an organisation to the various standards applicable to a GIS. The link to supply chains and supply chain management was briefly mentioned in Section 3.6. The last section of Chapter 3 examined the different applications of GIS, ranging from disaster management, risk management and crime mapping to the determination and location of new offices for the South African Department of Home Affairs.

The management of GIS was discussed in Chapter 4. The management processes needed for the implementation of a GIS in an organisation, the management of the day-to-day operation of the GIS and the maintenance of data and the GIS itself were considered. The discussion included workflow as a specific management tool to manage the creation of GIS products, the management of special GIS projects as once-off GIS projects, and the implementation of new concepts such as the change needed to implement the new Australian geodetic datum. Chapter 4 concluded the discussion on the reasons of failed GIS implementations. Most of the failures discussed in Chapter 4 occurred during the implementation phase of a GIS. Supply chain management could have addressed the failures with regard to project management, database (inventory) management and the ability of the staff to perform tasks necessary to create the GIS product, since it is designed to determine problems within the supply chain using various performance metrics. These metrics are then used to develop a strategy to improve the supply chain through the training of existing staff or through the acquisition of the necessary skills, hardware and software.

The purpose of this chapter, based on the discussions in Chapters 2, 3 and 4, is to integrate supply chains and supply chain management with GIS to illustrate that the establishment of supply chains and the management thereof is an alternative management approach to current GIS management practices, as well as to provide an answer to objective D: **Can supply chain management be linked to GIS in order to become a management tool for GIS?**

To answer the above research objective, this chapter uses the same format as Chapter 2. The topics discussed are illustrated using the Supply-Chain Operations Reference (SCOR) model to visualise the supply chain of a GIS unit.

5.2 Logistics management

Roberts (2003) indicated that three basic commodities flow through a supply chain, namely products, information and money. Within the GIS context products can be grouped as follows:

- Spatial data and its related non-spatial data (GIS products) such as roads, magisterial districts, elevation and satellite imagery.
- Other non-spatial data that can be used as part of the GIS product such as court statistics, which can be linked to a magisterial district.
- Hardware such as computers, servers, printers and plotters.
- Software such as GIS and other software that will be needed as part of the GIS product creation process. Examples are MSOffice, SAS and database management software such as Oracle or PostgreSQL.

In Section 2.4.2 logistics management was discussed under the headings of order processing, inventory, transportation, warehousing and network design. In this section these topics will be discussed in the context of GIS to illustrate the use of supply chains and supply chain management in the creation of a GIS product.

5.2.1 Order processing

Demand for GIS products, as discussed in Section 2.4.2, is the reason why a GIS is implemented in an organisation (Sections 3.4.5.1 and 4.3.2.7). It drives the system and enters the supply chain through order processing. The customer, internal or external to the organisation in which the GIS unit has been established, enters an order (order preparation) and kick-starts the process. The related process elements that are relevant are highlighted in Figure 5.1.

The other steps in order processing could include the following (Harrison, 2001; Min and Keebler, 2001; Roberts 2003):

- Order transmittal is where the customer mails the order for a GIS product or products, or places the order via telephone or online on the Internet. The corresponding Level 3 SCOR process element is D1.2 and D2.2. The process element description is: *Receive, enter and validate order* (Supply-Chain Council, 2001). If the GIS unit responds to a Request for Proposal (RFP) or a Request for Quote (RFQ) the following corresponding Level 3 process elements are D3.1 (*responding to the RFP or RFQ*) and D3.2 (*negotiate and receive contract*). **D** is used to indicate the SCOR management process **DELIVER** and D**1** is **Deliver Stocked Product**, D**2** is **Deliver Make-to-Order Product** and D**3** is **Deliver Engineer-to-Order Product**, which are the different process categories of the SCOR model. The terms *Stocked Product, Make-to-Order* and *Engineer-to-Order* were discussed in Section 2.5.2. The last numeral in D1.**2**, D3.**1**, D3.**2**, etc. indicates and describes the appropriate process element within the process category as given above.
- Order entry involves checking for order accuracy, availability of GIS products ordered, customer's ability to pay for the order and billing preparation. The SCOR process elements are D1.2 and D2.2.
- Order filling, which is discussed in Section 2.4.2.1, are those physical activities for preparing the order, and range from manufacture, assembly, picking and sorting to packaging for transportation, but in the context of creating a GIS product order filling is used to determine whether the GIS product is available in the data warehouse. If the GIS product is available in the data warehouse, a copy is made and shipped to the client. Examples of *Stocked* GIS products are the products of the Chief Directorate Surveys and Mapping as discussed in Section 3.5.2.2. The GDS process elements for *Stocked* or *Make-to-Order* GIS products are D1.3 and D2.3, which are defined as follows: *Reserve GIS product and determine delivery date* (Supply-Chain Council, 2001). For *Engineer-to-*

Order GIS products the SCOR process element is D3.3: *Enter order, commit resources and launch program*.

- Order status reporting, which ensures good customer service, allows the customer to track and trace the order from start to finish, and informs him when the order can be expected. This is done by the GIS unit and forms part of the customer relationship management that was discussed in Section 4.3.3 as well as SCOR process elements D1.3 and D2.3. For the *Engineer-to-Order* GIS product, the process element D3.4 *Schedule installation*, means that the GIS product will be installed at the customer's premises at a specified date (Supply-Chain Council, 2001). An example of an *Engineer-to-Order* GIS product is when a local government outsources the initial creation of the cadastre data to the consultant during the implementation of a GIS into the local government. The consultant then has to install the GIS product (cadastre data) in the data warehouse as discussed in Sections 3.4.5.1.6 and 4.3.2.7.
- Invoicing the customer. An invoice is made out and posted to the customer. Depending on the organisational set-up in which the GIS unit is situated, invoicing can be done by the organisation's accounting department. The GIS unit must ensure that the necessary information is made available to the accounting department to enable them to issue an invoice. If the GIS unit is a business on its own, it issues the invoice itself. The SCOR process elements are D1.13, D2.12 and D3.11. The process is defined as: *Invoice and receive payment* (Supply-Chain Council, 2001).
- Accounting activities. Accounting activities could include following: tracking of the invoice that has been send to a customer; ensuring that the customer adheres to the payment terms of the invoice; following up on defaulters; and closing the process once the correct amount has been received from the customer. The SCOR process elements are the same as those discussed in invoicing the customer.
- After-sales technical and services support can be rendered by a GIS unit if agreed with the customer. This function may be implemented with regard to an *Engineer-to-Order* GIS product. The minimum support a GIS unit

should give is the handling of faulty GIS products as part of the **DELIVER RETURN** (**DR1**) process category as discussed in Section 2.5.2.2.

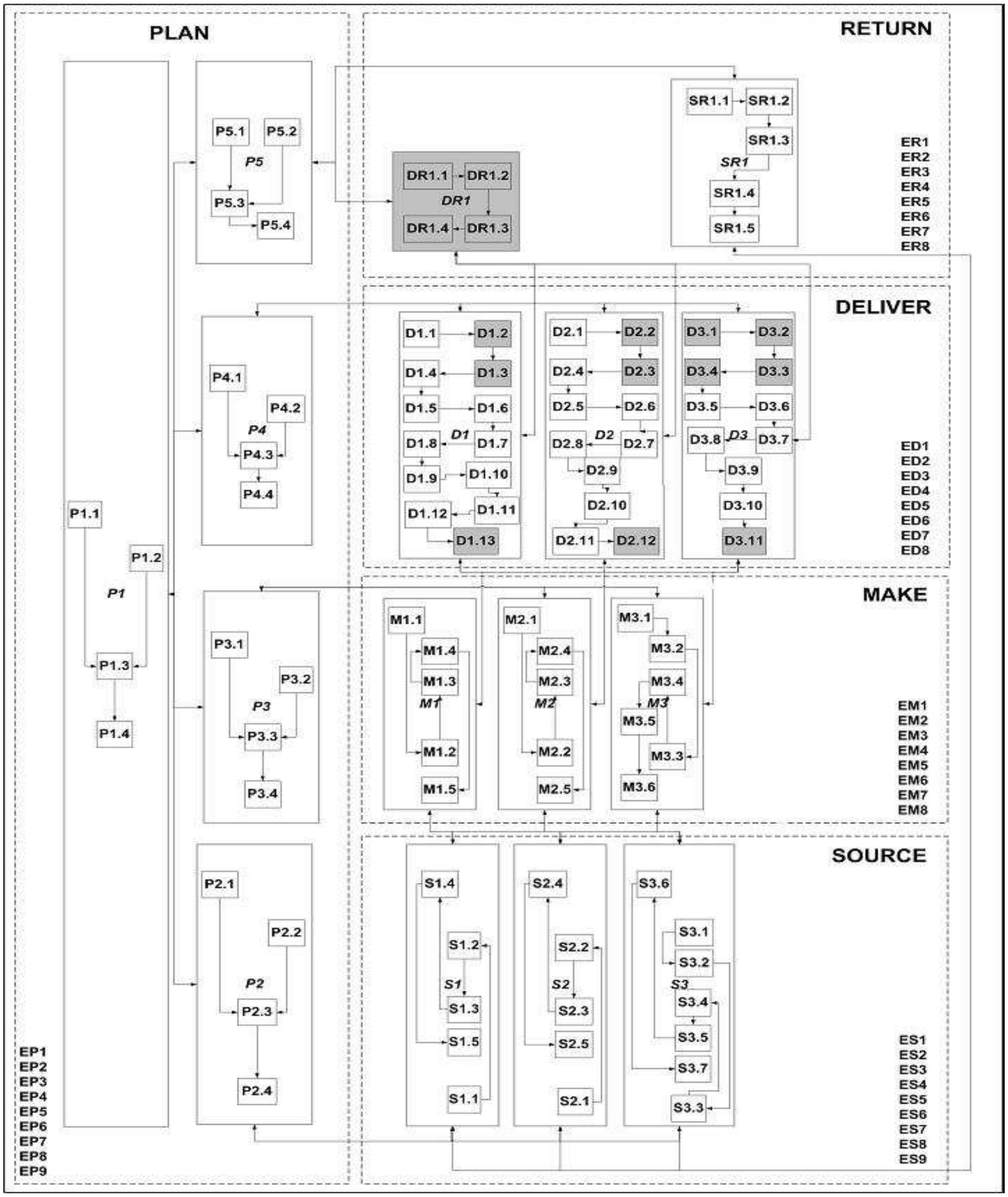

Figure 5.1: The process categories and elements involved in order processing and customer service[5]

[5] This figure and the others that are used in this chapter have been created by the student using the various process elements as described in the SCOR Version 5.0 manual published by the Supply-Chain Council in 2001.

Once an order is placed, the GIS product must be created and shipped. A GIS product consists of various spatial and related non-spatial data sets as well as other data sets of value to the creation of the GIS product that are either sourced from suppliers or created in-house. These parts form part of the inventory that is kept by a GIS unit. The next section looks at inventory in more detail.

5.2.2 Inventory

Inventory as discussed in Section 2.4.2.2 refers to the general definition of different materials that are stocked in a warehouse, such as automotive parts, completed products (i.e. retail consumables, motor vehicles or furniture) and work-in-progress stock and their associated costs.

In the context of GIS, inventory is defined as the spatial and related non-spatial data sets such as road networks and other data. The spatial part of the road network gives the geographic location of the road defined by nodes (points) and links (lines) between the nodes. The related non-spatial data is the attribute data which includes the topology of the road network describing direction, type of node such as a crossing or overpass and other data such as road width, speed, travel time and road surface type. Other data sets could be accidents that occur on the road network and road maintenance information. These data sets can be linked to the road network using a field in the dataset that corresponds to a similar field in the related non-spatial dataset of the road network. Other examples of GIS inventories are given in Section 3.5.

These data sets are stored on a disk, server or in a data warehouse. A disk, server or data warehouse has the same function as a traditional warehouse in which inventory is stored. For the purpose of this study the term data warehouse is used to include a disk and/or a server on which data are stored and retrieved from. Data warehouses are discussed in Section 3.4.5.1.6 under the sub-heading *Creating databases*. In Section 2.4.2.2 the following inventory types were identified (Roberts, 2003), namely:

- Cycle stock.

- In-process stock.
- Safety stock.
- Seasonal stock.
- Promotional stock.
- Dead stock.

For the purpose of this study the following stock (data sets) types can be used in the context of GIS, namely:

- Cycle stock is the current spatial dataset and its related non-spatial and other data sets relevant to the GIS unit as well as the completed GIS products that were created by the GIS unit. Examples of cycle stock are satellite images that are used for change-detection GIS products, cadastral maps, 1:50 000 vector maps, electrified villages and the electricity networks. Examples of completed GIS products are change-detection GIS products and site-selection GIS products (de la Rey, 2006).
- In-process stock refers to those data sets that are stored in the data warehouse during the creation of a GIS product. An example of an in-process stock is a road dataset that is in the process of being updated (data maintenance). The new roads have been added, but the data still need to be cleaned up, which can take several days depending on the amount and quality of the new road data. During the cleaning process the GIS user will place the data in the data warehouse as in-process stock until the cleaning is completed. The updated road dataset will then be stored in the data warehouse as cycle stock. The management of data maintenance is discussed in Section 4.3.4.
- Dead stock refers to redundant data sets that are still stored in the data warehouse. These data sets are no longer of immediate value to the GIS unit and data sets should be archived and removed from the data warehouse. The maintenance of archived data sets is discussed in Section 4.3.4.

Christopher (1998) mentions five different approaches to inventory management. These approaches, which are examined in Section 2.4.2.2, are:

- Economic Order Quantity (EOQ).
- ABC inventory control system.
- Material Requirement Planning (MRP), which evolved into Material Resource Planning (MRP II) and Enterprise Resource Planning (ERP).
- Distribution Resource Planning (DRP).
- Just-in-Time (JIT).

Owing to the nature of GIS operations, namely the storage, retrieval, transformation, manipulation and displaying of spatial and related non-spatial data, MRP is an adequate management approach to managing data sets (inventory) in a data warehouse of a GIS unit. As mentioned in Section 2.4.2.2, MRP is used to determine which materials are needed to create a specific product. In the context of GIS, the materials needed are the different spatial and related non-spatial data sets as well as other data sets.

As shown in Section 2.4.2.2, MRP takes into account what is available in a data warehouse, what data need to be sourced as well as when the data will be used. The metadata catalogue, which contains the metadata documents of the data stored in the data warehouse, could be part of a MRP. A cartographic model shows the different initial spatial and related non-spatial data sets and sequence of functions and operations (i.e. overlay, buffering, clip, etc.), as well as in-process spatial data (e.g. the buffered roads and lakes data sets) that are required to create a GIS product such as suitable sites for development based on several criteria (Bolstad, 2005). An example of a cartographic model is given in Figure 3.12. The initial spatial and related non-spatial data sets as well as the initial other data sets are part of the MRP. The model created in ESRI's ModelBuilder is a special form of cartographic model as described by Bolstad (2005), and the initial spatial and related non-spatial data sets are part of the MRP. Thus in its simplest form the MRP can be a straightforward list showing all the available data in a data warehouse based on the metadata catalogue and the data needed by each different GIS product creation project as defined by the cartographic model, or any other form of listing of required data. The required data lists for each project in the MRP should have a date linked to it. By combining the required data lists in the MRP and comparing the combined list with the list of data in the data warehouse as listed in the MRP at specified time intervals such as a financial year, it may be possible to identify dead stock in the data warehouse, which could then be archived and removed from the data warehouse. MRP is used in the **PLAN**, **SOURCE** and **MAKE** management processes of the SCOR model (Supply-Chain Council, 2001).

As mentioned above, GIS products are created by demand once each GIS product has been identified, which is the function of P1.1 in P1 (**Plan the supply chain)**. P1.1 is *Identify, prioritise and aggregate supply chain requirements*. The MRP for each GIS product is developed on the basis of the information provided by P1.1 and used as input into P2 (**Plan SOURCE**) and P3 (**Plan MAKE**). The Level 3 process elements are P2.2 (*Identify, assess, and aggregate product resources*) which uses the MRP to determine which data (spatial and related non-spatial and other data) are available and which data need to be sourced from suppliers. Figure 5.2 highlights these process elements in the SCOR model. P3.2 is *Identify, assess and aggregate product resources* that use input from the MRP to determine the data as well as other resources such as GIS software, paper, and digital media needed to create a GIS product. In P2 (**Plan SOURCE**) the different spatial and related non-spatial data, as well as any other data that needs to be sourced from the various suppliers, are identified. These identified data sets need to be transported to the GIS unit. Transportation in the context of GIS product creation is discussed in the next section.

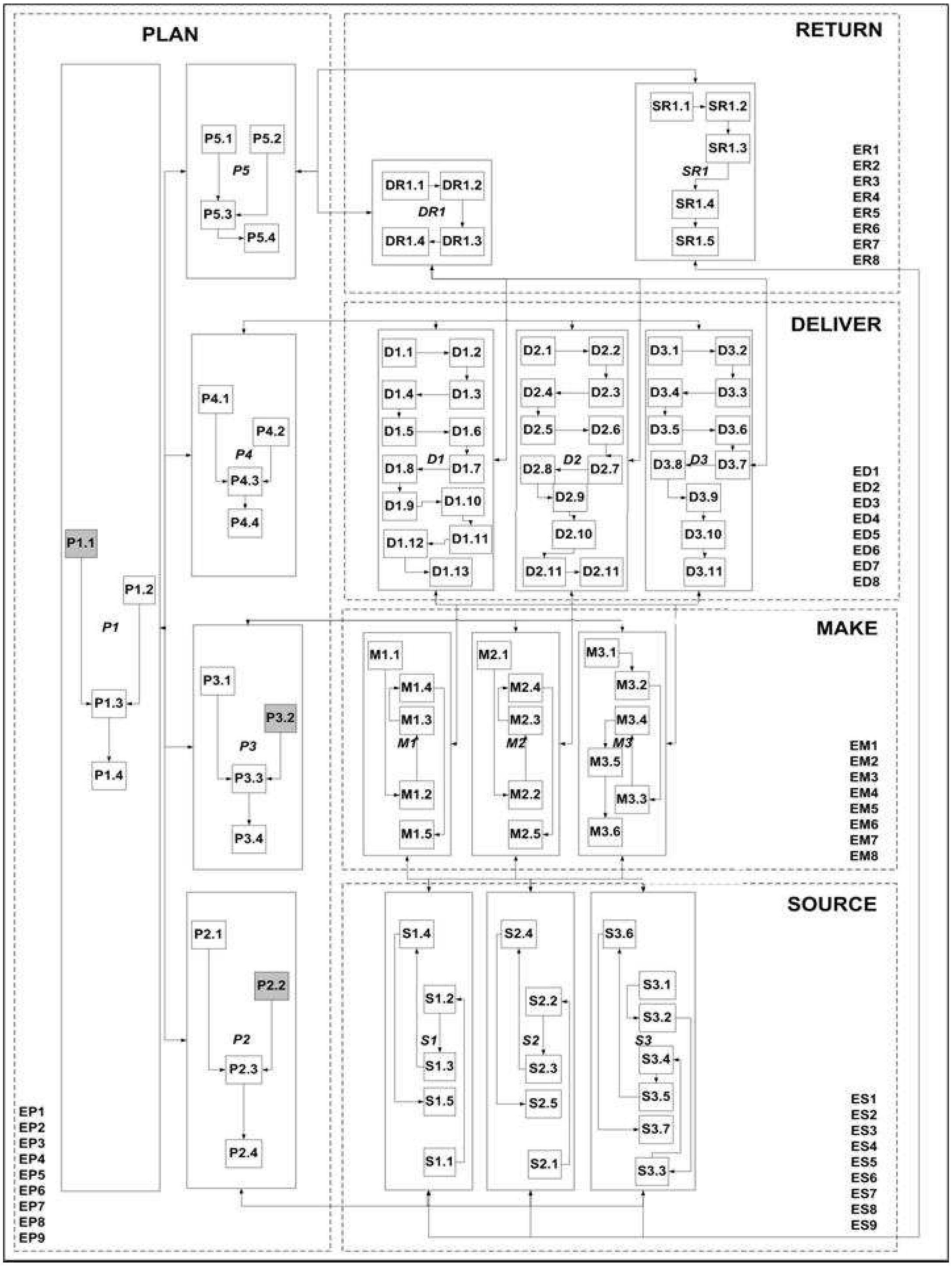

Figure 5.2: Process elements that provide input to and need output from a MRP

5.2.3 Transportation

In Section 2.4.2.3 it was mentioned (Min and Keebler, 2001: 246) that *transportation is the spatial linkage for the physical flows of a supply chain*. The modes of transport discussed in the abovementioned section are air carriers, motor carriers, rail carriers, water carriers and pipelines. Within the context of GIS and for the purpose of this study, the modes of transport are defined as follows:

- Motor carriers could be either a courier company contracted by the GIS unit to transport the GIS data on CD-ROM, DVD, removable hard disk, flash memory stick or in hardcopy format (maps) or a driver employed by the organisation in which the GIS unit is situated or a staff member of the GIS unit itself using a motor vehicle.
- Air carriers that are used by the contracted courier company to transport the GIS products or other data.
- A local area network (LAN) that is used to transfer data and GIS products from or to the GIS unit and different users (customers and suppliers) within an organisation.
- A wide area network (WAN) of a distributed organisation such as Eskom, which is used to transfer data and GIS products from or to the GIS unit and different users (customers and suppliers) within the organisation.
- The Internet, which is used to source or distribute data and GIS products. Examples are the Geography Network (see Section 3.2.5 for a short discussion of the Geography Network), GIS Web portals (Section 3.2.5), GIS Web services such as SA-ISIS that act as spatial and related non-spatial data brokerages, FTP sites and e-mail. The latter can be used if the data or GIS product is a small dataset.

In the linking of the transport of spatial and related non-spatial data, GIS products and other data to and from the GIS unit to SCOR Level 3 process elements, the following process elements have been identified (see Figure 5.3):

- ES (**Enable SOURCE**) and ED (**Enable DELIVER**) are the enabling processes that enable the supply chain to function and both ES.6 (*Manage incoming product*) and ED.6 (*Manage transportation*) are the Level 3 enabling process elements that deal with the transportation of spatial and related non-spatial data, GIS products and other data to and from the GIS unit. ED.6 deals specifically with courier selection.
- ES.6 provides input to S1.1 (*Schedule product deliveries*), S2.1 (*Schedule product deliveries*) and S3.3 (*Schedule product deliveries*). S1 is **Source Stocked Product**, S2 is **Source Make-to-Order Product** and S3 is **Source Engineer-to-Order Product** process categories that are used to model the sourcing of spatial and related non-spatial and other data from identified suppliers.
- ED.6 provides input to D1.10 (*Generate shipment documentation, verify credit and ship GIS product*), D2.9 (*Generate shipment documentation, verify credit and ship GIS product*), and D3.8 (*Generate shipment documentation, verify credit and ship GIS product*).

Once the sourced spatial and related non-spatial and other data arrive at the GIS unit, they need to be placed into the data warehouse. GIS products for delivery are sourced from the data warehouse and shipped to the customer using any form of transport mode and medium such as DVD and CD-ROM. Data warehousing will be discussed next.

5.2.4 Data warehousing

The data warehouse concept was discussed in Section 3.4.5.1.6 and inventory in Section 5.2.2. This section looks at the activity of transferring data to and from the data warehouse. In Section 2.4.2.4 the following warehousing functions were identified, namely:

- Cross-docking
- Stockpiling
- Stock mixing
- Postponement

- Reverse logistics
- Spot stocking
- Contingency protection.

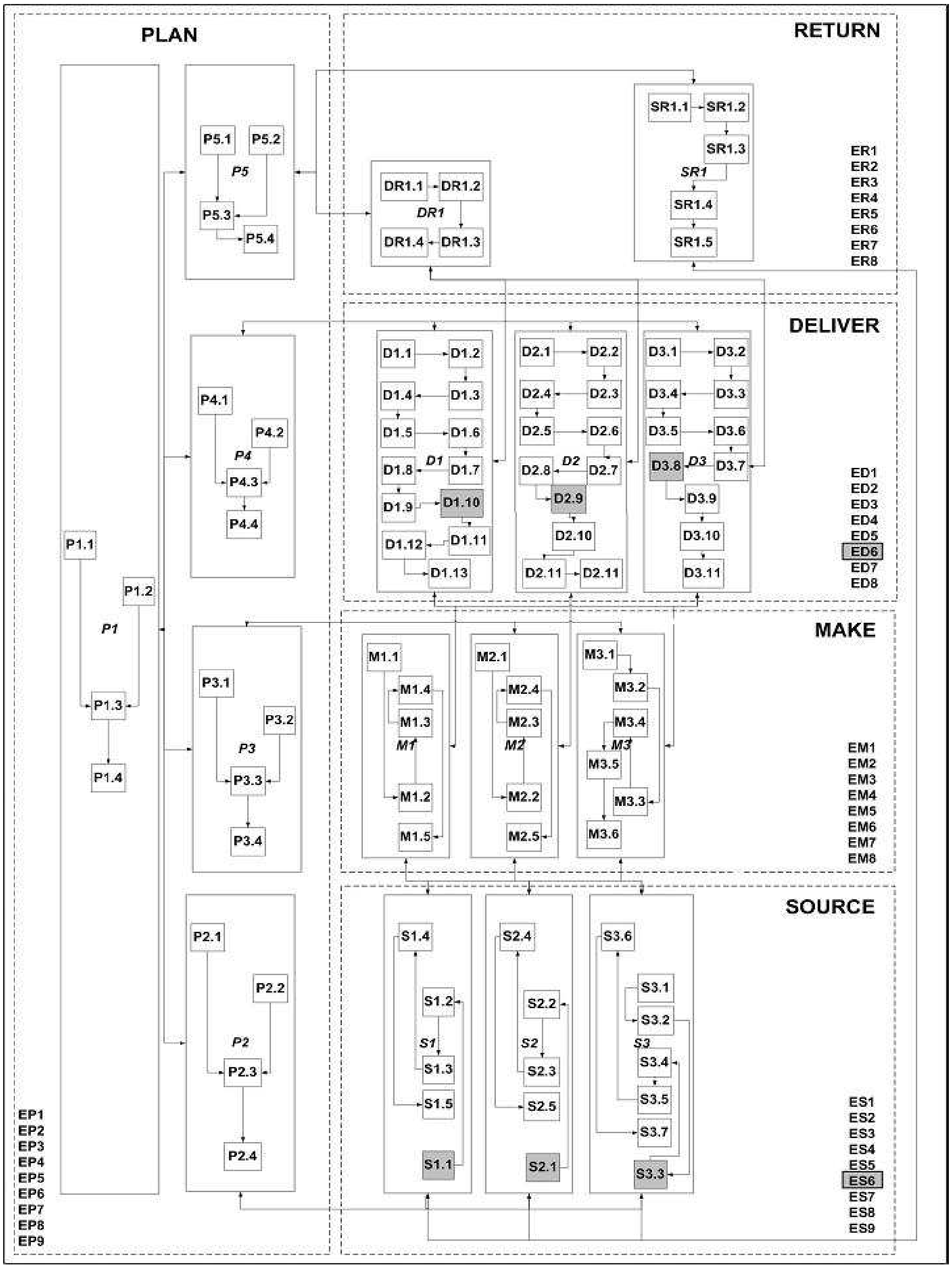

Figure 5.3: Enable processes and process elements that deal with transportation of materials

In the context of GIS, storing spatial and related non-spatial and other data as well as GIS products in a data warehouse can be seen as stockpiling to meet any demand on the GIS unit, depending on whether the GIS unit creates Stocked or Make-to-Order GIS products. In the case of engineer-to-Order GIS products, depending on the data needed, the GIS unit may extract existing data from the data warehouse, while the rest is sourced from suppliers. The backing-up of the data warehouse at a different location than the original data warehouse is a contingency protection measure.

The functions of a data warehouse can be identified as follows:

- The receiving of sourced spatial and related non-spatial and other data, including the verification and matching of the data to the purchase order (GDS Level 3 process elements S1.2 (*Receive product*); S2.2 (*Receive product*); S3.4 (*Receive product*); S1.3 (*Verify product*); S2.3 (*Verify product*) and S3.5 (*Verify product*)) as well as GIS products that have been completed by the GIS unit during the **MAKE** processes, namely M1.4 (*Transfer produced GIS product*); M2.4 (*Transfer produced GIS product*); M3.5 (*Transfer produced GIS product*). M1 is **Make-to-Stock,** M2 is **Make-to-Order** and M3 is **Engineer-to-Order**. Figure 5.4 shows the various process elements involved.
- The above data and GIS products are stored at predetermined locations within the data warehouse as developed by the data warehouse manager. Locations can be directories that store similar data. An example is infrastructure which can be subdivided into roads, rail, air, water and pipelines. Roads can be further subdivided into urban and non-urban roads. Water can be subdivided into harbours, sea routes, rivers and lakes as well as canals. The management of data was discussed in Section 4.3.3.

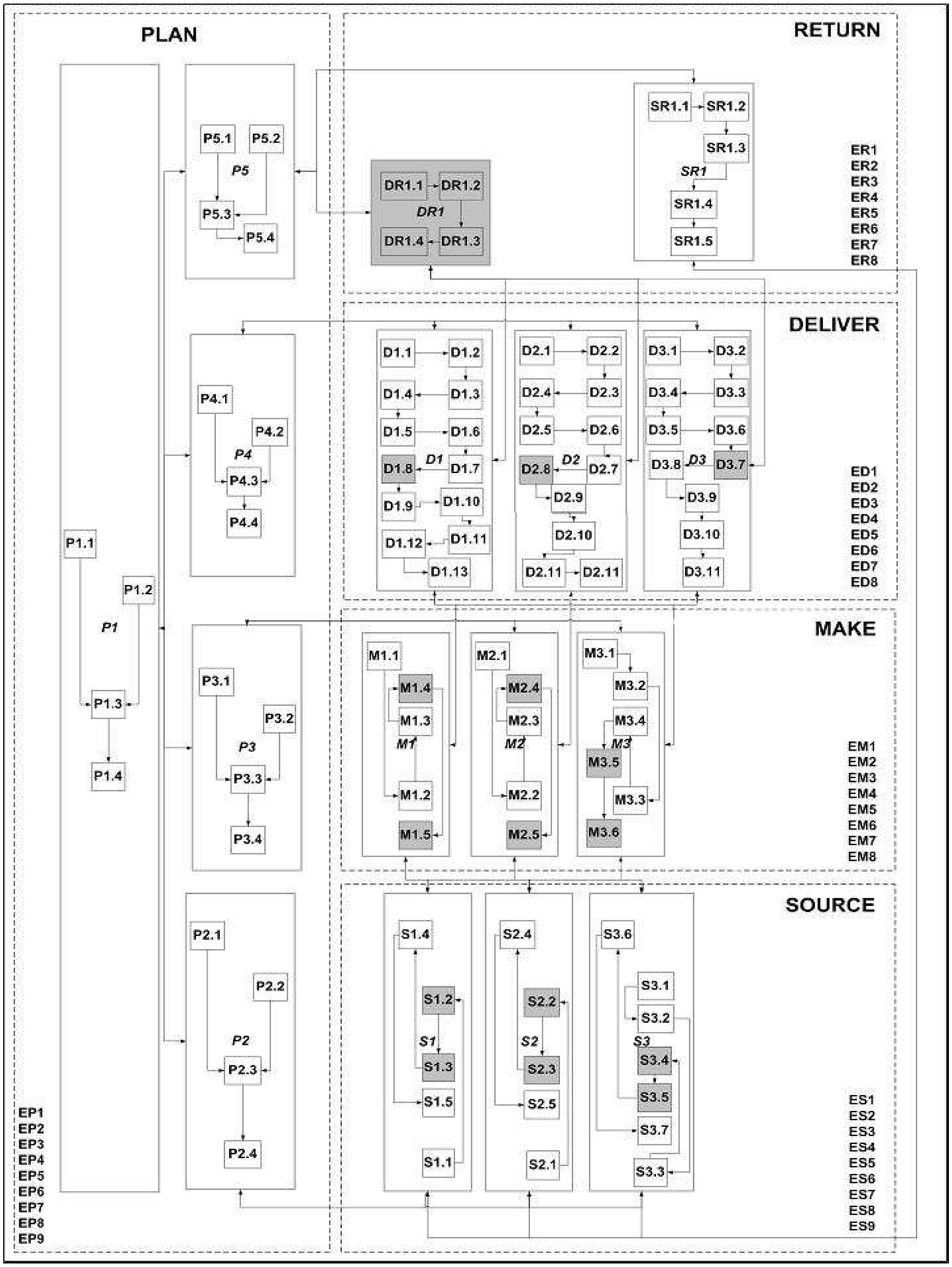

Figure 5.4: Process categories and process elements that are involved in data warehousing

- The next function of a data warehouse is to make the abovementioned data and GIS products available for extraction from the various locations of the data warehouse based on the need of the GIS unit. The SCOR Level 3 process elements, as indicated in Figure 5.4, are M1.5 (*Release produced GIS product*) and D1.8 (*Receive the product at the data warehouse*); M2.5 (*Release produced GIS product*) and D2.8 (*Receive the product at the data warehouse*); and M3.6 (*Release produced GIS product*) and D3.7 (*Receive the product at the data warehouse*).

- The data warehouse also receives defective GIS products from customers, which are then released to the GIS unit for correction. The corrected GIS product follows the same actions as per the DELIVER processes. The SCOR Level 2 process category is DR1 (**Deliver Return Defective Product**).

The above functions of the data warehouse are similar to the functions of a warehouse as discussed in Section 2.4.2.4.

5.2.5 Network design

A data warehouse as described in the previous section and in Section 5.2.2 is part of a supply chain network since it receives spatial and related non-spatial and other data from internal and external suppliers as well as GIS products from the GIS unit and also releases GIS products to internal and external customers. In this supply chain network information and money flow up and down the supply chain. As mentioned in Section 2.4.2.4, the aim is to make the supply chain network as efficient and cost effective (optimal) as possible. The same can be done in the GIS environment. Establishing proper relationships with suppliers to ensure timely delivery of ordered spatial and related non-spatial data or other data will ensure that projects will not be delayed. SCOR can thus be used to model the chain using the SCOR management processes to identify problems within the supply chain network and institute actions to optimise the supply chain.

Using SCOR to improve the network will also improve the operational management of the GIS unit as discussed in Section 4.3.3, since SCOR embraces the operations (**MAKE**); customer relationship management (**DELIVER**); and order management, which involves both placing orders with suppliers (**SOURCE**) and receiving orders (**DELIVER**). The management process **RETURN** is seen as part of customer relationships since it will enable the GIS unit to deal speedily with faulty GIS products. **RETURN** also assists the GIS unit to deal effectively with suppliers when receiving faulty data. The management process **PLAN** guides the GIS unit to optimise the supply chain by balancing the demand on the supply chain with the resources available and those that need to be sourced. ES.7 (ES – **Enable Source**) (see Figure 5.4) is the SCOR Level 3 enable process that is used in the SCOR model to manage the supplier network.

Third-party logistics (3PL) as mentioned in Section 2.4.2.4 will be restricted in the context of GIS to the use of courier services to move GIS products, spatial and related non-spatial and other data between suppliers, the GIS unit and customers. A GIS portal or a Geography Network can assume the role of a 3PL, where it provides access to spatial and related non-spatial data repositories as well as the processes to move the data from and to these repositories using the Worldwide Web or the Internet.

5.3 Materials management

Section 5.2 looked at the various logistics management of the supply chain to enable the movement of materials (spatial and related non-spatial data, other data and GIS products) between the role-players of the supply chain at an optimal level. Good logistics will be in vain if the material that moves between the different role-players is not managed properly. This section discusses material management from a GIS unit's point of view regarding the different activities as identified in Section 2.4.3.

5.3.1 Procurement

This section discusses the procurement of different materials for the GIS unit to enable it to operate efficiently and effectively. The materials that are procured in the context of GIS are the following:

- Spatial and related non-spatial and other data

- GIS products
- Software
- Hardware
- Stationary
- Other equipment and sundries such as a laser scanner, GPS devices, shelves and furniture.

Roberts (2003) identified the following activities (Section 2.4.3.1) with regard to the procurement process, which can also be applied in the GIS context:

- Identify the need to procure an item or items (raw materials such as spatial and related non-spatial and other data, GIS products or service). This is based on requirements inside the firm or on customer demand. The identified need is based on outputs from the **PLAN** management process of the SCOR model. The SCOR Level 3 process element is P1.1 (*Identify, prioritise and aggregate supply chain requirements*), as indicated in Figure 5.5, with inputs from data collected on the different GIS products produced by the GIS unit, as well as collaboration with the GIS unit's customers and suppliers and aligning the supply chain plan with the GIS unit's financial plan.
- Define and evaluate the user requirements of the item that must be met. This is done to determine whether the required item is a stocked, a Make-to-Order or an Engineer-to-Order item, which has different procurement requirements as defined in S1 (**Source stocked product**), S2 (**Source Make-to-Order product**) or S3 (**Source Engineer-to-Order product**).
- Once the requirements are met, decide whether it is cheaper to make the item in-house or to procure it, such as whether it would be preferable for the GIS unit itself to digitise a road network or to acquire it from a supplier who creates the required road data.
- Identify the type of purchase, i.e. a straight re-buy or a modified re-buy from existing suppliers (a modified re-buy means changing from one existing supplier to another existing supplier) or a new buy. A new buy means identifying a new supplier from which to buy. ES.7 (*Manage*

supplier network) and ES.3 (*Maintain source (supplier) data*) are the SCOR Level 3 source enable processes used during this activity (Supply-Chain Council, 2001).

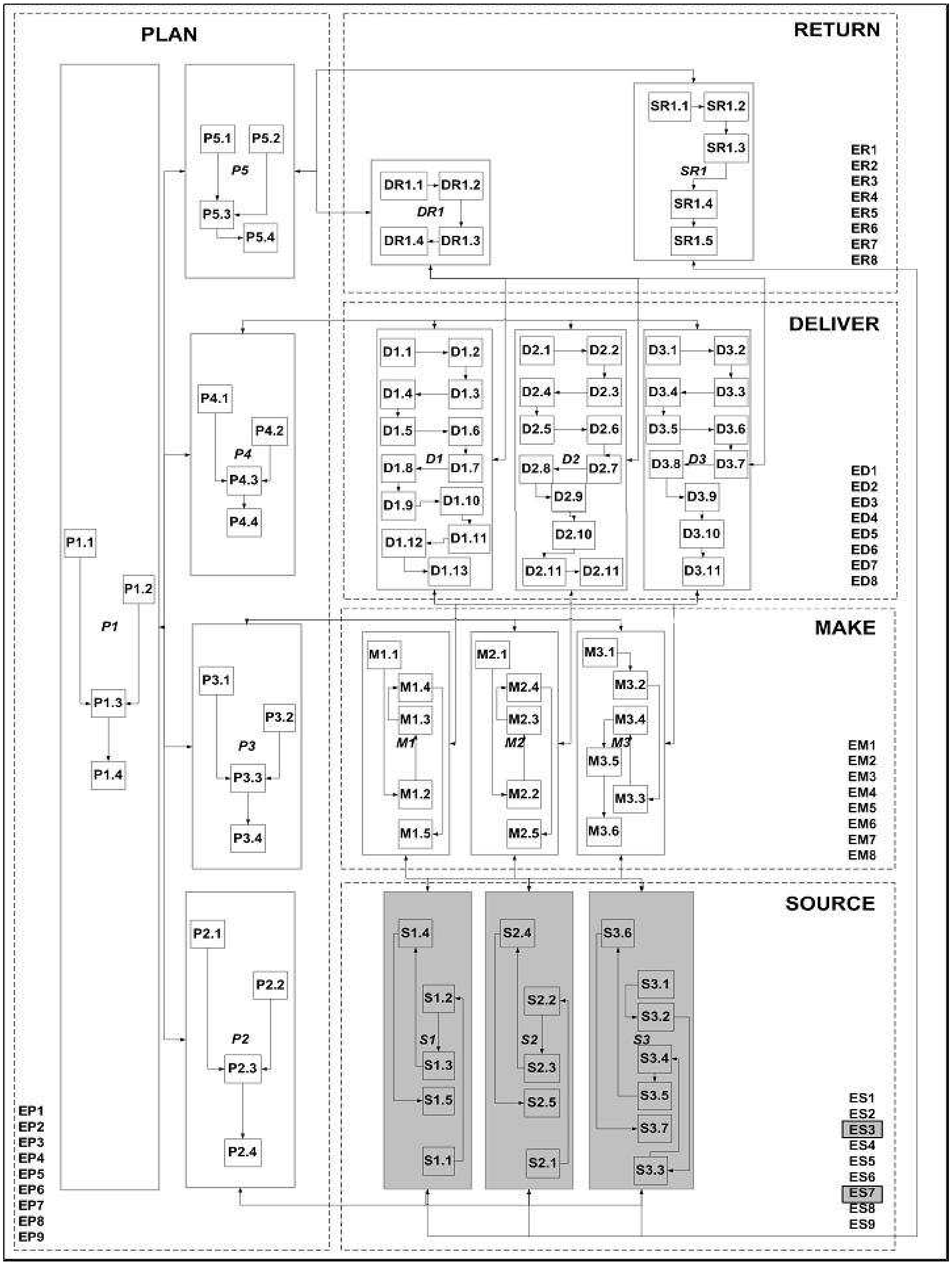

Figure 5.5: Enable processes and process categories that are involved in procuring materials for the GIS unit

- If the item has to be acquired from a new supplier, the GIS unit must conduct a market analysis of possible suppliers of the item and base the buying strategy on key indicators within that market.
- From the market analysis, identify possible suppliers.
- Pre-screen the identified suppliers based on demand criteria, based on the input from ES.3 and ES.7 (see Figure 5.5).
- Evaluate the remaining supplier base based on the best fit of negotiable user requirements using several methods such as competitive bidding or benchmarking as per the **SOURCE** management process of SCOR.
- Receive delivery of procured item from the selected supplier as per the **SOURCE** management process of SCOR.
- Make a post-purchase performance evaluation to establish that the item meets the pre-set requirements; if not, then corrective action must be taken as per requirements of ES.3 and ES.7 source enable process in SCOR.

The above activities, in addition to the SCOR processes discussed above, can be managed in a four-step process identified by Roberts (2003) in Section 2.4.3.1. The GIS unit can use e-Procurement to procure materials needed by the GIS unit. The benefits and the issues with regard to e-Procurement are given in Section 2.4.3.1.

5.3.2 Warehousing

Warehousing deals with the handling and storage of ordered spatial and related non-spatial and other data as well as ordered GIS products and is discussed in detail in Section 5.2.4.

5.3.3 Production planning

This section looks at the production planning (P3 of the SCOR model as shown in Figure 5.6) that a GIS unit needs to do, and must be based on the estimated demand for a specific product. GIS units receive regular requests on an ad hoc basis, which are comparatively small requests for a GIS product. This is especially true of a GIS unit in an organisation where, for example, there is a request for a map of South Africa showing the organisation's main retail outlets, or a map showing the national road network of South Africa, and so forth. These small ad hoc requests impede the production of complex GIS products which take longer to complete (de la Rey, 2006). When the GIS unit does its production planning, it needs to take ad hoc requests into account to ensure the timely delivery of its complex GIS products.

In Section 2.4.3.3 four different production systems are discussed based on the type of demand made on the products, which can also be applied in the context of GIS:

- System 1 is a production system that reduces cost and increases the efficiency of producing functional products (GIS products in the context of GIS) in a stable market. Chief Directorate Surveys and Mapping could be such a unit as they could use supply chains and supply chain management to improve their production system to reduce their costs and be more efficient in creating their GIS products, such as 1:50 000 vector maps.
- System 2 is a flexible production system that enables a GIS unit to react quickly to ad hoc requests, but also enables the unit to complete longer-term GIS products on time. Most of the GIS units will fall into this category. Using supply chains and supply chain management, these units could set up their production to enable them to deal with such requests.
- System 3 is a dispersed production system where components of a GIS product or GIS products are made at different GIS units and managed by a specific GIS unit. An example of this production system is the distributed data production as described by Li and Coleman (2003), where workflows were used to monitor and improve the data quality of the GIS products. Li and Coleman only addressed the quality control aspect of supply chain management, but it is felt that implementing supply chain management would improve the distributed production of a GIS product even further.

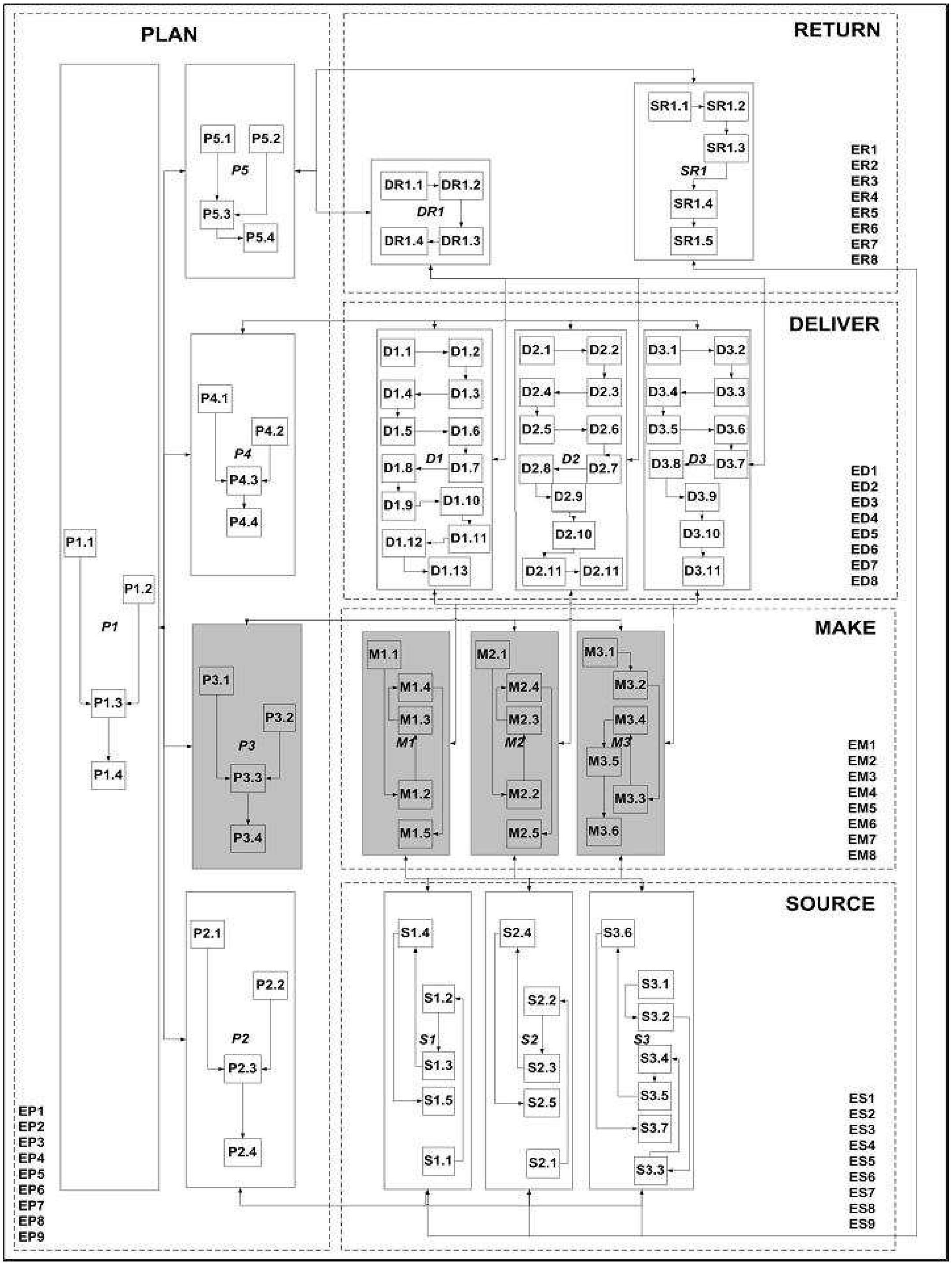

Figure 5.6: Process categories involved in the creation of a GIS product

- System 4 is a production system where products are built to order (Make-to-Order in the SCOR model), where GIS units create GIS products using data that change continuously or ages quickly, such as land use/land cover data or satellite imagery. As described in Section 2.4.3.3, the rapid change is driven by the customer, but in the context of GIS the rapid change is driven by the rapid changing of the data over time. The Satellite Applications Centre at Hartebeeshoek in South Africa is such a unit that creates Make-to-Order GIS products based on satellite imagery.

Relating to the above, the production planning is done in P3 (**Plan MAKE**), which includes the identification of and inputs from the different **MAKE** processes, namely M1 (**Make-to-Stock**), M2 (**Make-to-Order**) and M3 (**Engineer-to-Order**) as shown in Figure 5.6 above. During production planning the different spatial and related non-spatial and other data as well as GIS products are identified. Those that need to be ordered from suppliers will be delivered to the GIS unit. Inbound transportation looks at the delivery mechanisms employed by suppliers to deliver the data and GIS products to the GIS unit.

5.3.4 Inbound transportation

Inbound transportation is the spatio-temporal link between the GIS unit and its suppliers. The transportation of spatial and related non-spatial and other data as well as GIS products has been discussed in Section 5.2.3. The process of receiving the inbound products as listed above will be discussed next.

5.3.5 Receiving

This section looks at the physical reception and verification of ordered spatial, related non-spatial and other data as well as GIS products by the GIS unit. Data warehousing deals with the receiving of sourced data including verifying and matching it to the purchase order (SCOR Level 3 process elements S1.2 (*Receive product*); S2.2 (*Receive product*); S3.4 (*Receive product*); S1.3 (*Verify product*); S2.3 (*Verify product*) and S3.5 (*Verify product*) as discussed in Section 5.2.4. This section discusses receiving and verifying in more detail.

The *Receive product* (S1.2, S2.2 and S3.4) process element deals with the physical reception of the data or GIS products, and the output of this action is the receipt and verification, indicating that the correct data and/or GIS products have been received as per order to the supplier by the GIS unit. *Verify product* (S1.3, S2.3 and S3.5) is the physical verification of the data or product itself and establishes that the product is in the correct file format, has metadata and that it complies with the various GIS ISO and national standards (see Section 3.4.5.3) as stipulated by the GIS unit.

Another function of receiving is the receipt of defective GIS products from customers. The processes involved in the return of defective GIS products created by the GIS unit to the unit in the SCOR model as adapted in GDS are given in the **RETURN** management process section as discussed in Section 3.5.2.1. The SCOR Level 2 process category is DR1 (**Deliver Return Defective Product**) and the related SCOR Level 3 process elements are DR1.1 (*Authorise defective product return*), DR1.2 (*Schedule defective return receipt*), and DR1.3 (*Receive defective product*).

Cost-effective and correct handling and management of data as well as GIS products (materials) are of importance to ensure an effective and efficient supply chain. This section looked at the activities concerned with materials handling and management, such as inbound logistics, inventory and quality control. This and the previous section looked materials management and logistics and how it is important to the supply chain and supply chain management, but the correct materials and finished GIS products from the GIS unit have to be moved along the supply chain. The next section investigates operational issues regarding the supply chain and supply chain management to establish which materials and finished GIS products have to be moved along the supply chain. The abovementioned process elements are highlighted in Figure 5.7.

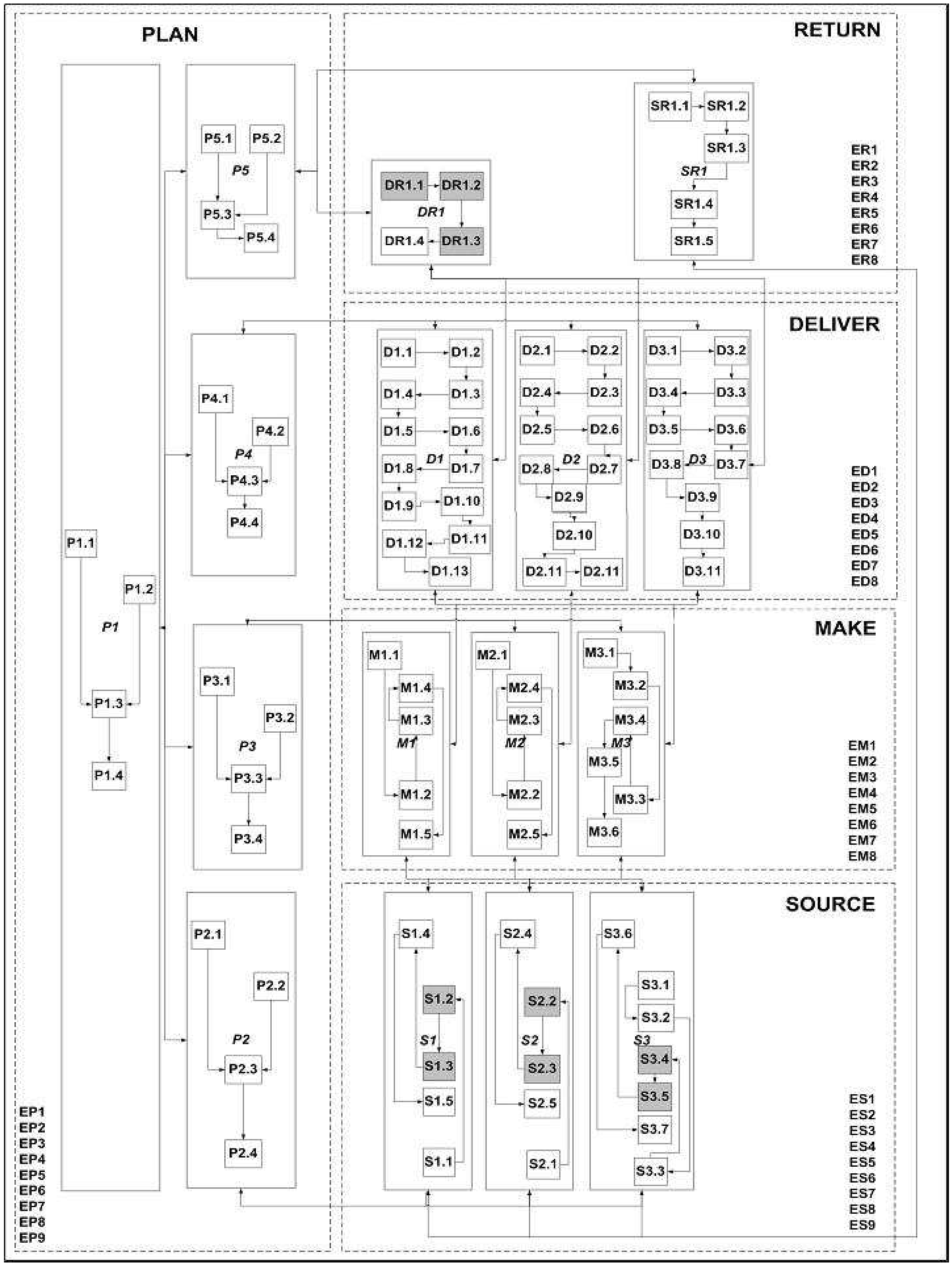

Figure 5.7: Process elements involved when a GIS unit receives spatial, related non-spatial and other data

5.4 Operations

5.4.1 Introduction

Operational management of GIS was discussed in Section 4.3.3, with the focus on customer management, system administration and support, operations support for the day-to-day running of the GIS, database management, applications management and the management of standards and conventions as well as the management of personnel and the long-term management of the GIS. This is necessary for the successful operation of the GIS unit, and this section looks at the concepts of forecasting, operations planning and quality management that can be used to further improve the operational management of a GIS unit as well as to excel in fulfilling the customers' needs.

5.4.2 Forecasting

In Section 2.4.4.2 forecasting was divided into two groups, namely qualitative and quantitative forecasting techniques. Qualitative forecasts rely on the opinions and intuition of experts. Several qualitative and quantitative methodologies are discussed in Section 2.4.4.2, and it is suggested that in the GIS context a qualitative approach should be used for forecasting using methods such as the Sales Force Composite and/or consumer surveys.

In Section 2.4.4.2 the concept of Collaborative Planning, Forecasting and Replenishment (CPFR) is mooted to improve the supply chain partners' forecasting abilities and to optimise the supply chain to meet the forecast demands effectively and efficiently. It is therefore suggested that GIS units should use some form of CPFR to improve their ability to create and deliver GIS products more efficiently and effectively. The benefits of using CPFR as given by Wisner, Leong and Tan (2005) are discussed in Section 2.4.42, and the following are applicable to the GIS unit and its supply chain partners:

- Strengthens supply chain partner relationships.
- Provides analyses of sales and order forecasts upstream and downstream of the GIS unit's supply chain.

- Uses sales data to improve forecast accuracy.
- Manages the demand chain by exception and proactively eliminates problems before they appear.
- Allows collaboration on future requirements and plans.
- Uses joint planning and management of promotions.
- Integrates planning, forecasting and logistics activities.
- Provides efficient GIS product category management and understanding of consumer GIS product needs.
- Provides analyses of key performance metrics such as forecast accuracy, GIS product lead times and inventory turnover to reduce supply chain inefficiencies, improve customer service and increase sales and profitability.

Section 2.4.4.2 gives a guideline on how to implement CPFR between supply chain members of the GIS unit. The results of the forecast(s) are used as input(s) to plan the supply chain. The inputs are used in the SCOR Level 2 process category P1 (**Plan the supply chain**). The SCOR Level 3 process elements that use the information are P1.1 (*Identify, prioritise and aggregate supply chain requirements*) and P1.2 (*Identify, prioritise and aggregate supply chain resources*) as shown in Figure 5.8. Once collaboration between the GIS unit and the other supply chain members (upstream and downstream), and the forecasts have been established based on CPFR, the supply chain members need to plan the productions. The following section discusses several aspects of planning production from long-term to short-term perspectives.

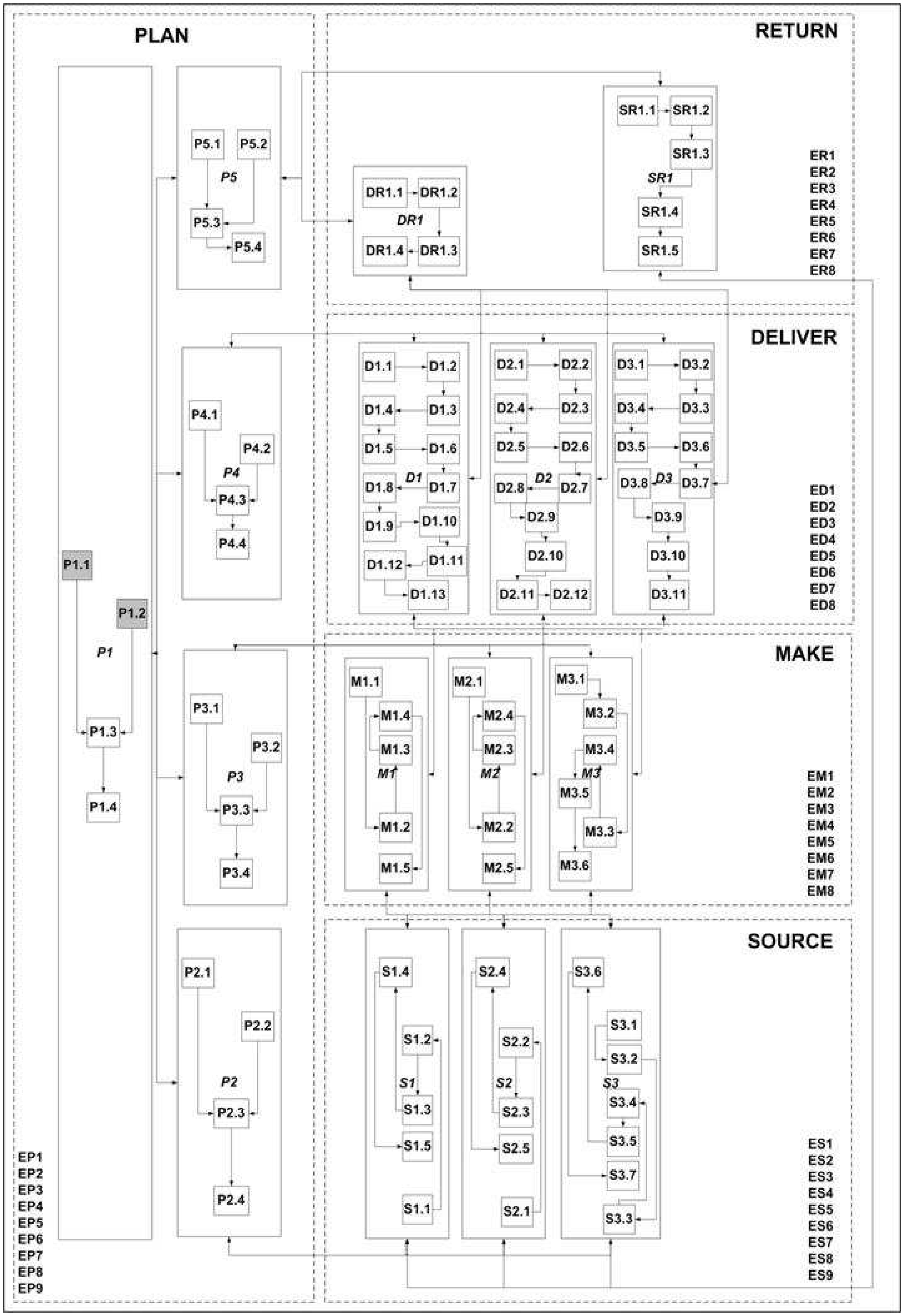

Figure 5.8: The process elements that require forecasting results

5.4.3 Operations planning

As discussed in Section 2.4.4.3 Wisner, Leong and Tan (2005) indicate that operations scheduling and inventory management are two of the most important activities to ensure the effectiveness and efficiency of an optimal supply chain. Operations planning draws on the information obtained from forecasting as discussed in the previous section. As with the SCOR Level 2 process categories of P1 (**Plan the supply chain**), P2 (**Plan Source**), P3 (**Plan Make**), P4 (**Plan Deliver**) and P5 (**Plan Return**), it balances capacity or supply resources (labour, equipment and materials) with forecast output (needs). They are managed by two enable planning processes, namely EP.3 (*Manage PLAN data collection*), which manages the collection of supply chain data and the results of CPFR activities necessary to balance the resource and demand requirements, and EP.7 (*Manage planning configuration*), which manages the collection of detailed information on spatial, related non-spatial and other data as well as GIS products requirements, equipment and other resources needed to meet the demand on the supply chain by customers. There are three levels of operations planning, namely long, medium and short-term planning. All three planning levels provide input into the different SCOR Level 3 process elements. Figure 5.9 shows the relevant enable processes and process elements that are involved in operational planning.

The long-term operational planning is known as the aggregated production plan (APP) and the resource requirement planning (RRP). Section 2.4.4.3 gives a detailed discussion on APP and RRP. The APP disaggregates the forecast(s) into specified time periods and determines the number of hours and size of the work force needed to create the different GIS products needed to meet the forecast demand. RRP gives the gross number of labour and computing hours needed to meet the demand. This information is managed by EP.3 and gives input into the following SCOR Level 3 process elements:

- P1.1 (*Identify, prioritise and aggregate supply chain requirements*)
- P1.2 (*Identify, prioritise and aggregate supply chain resources*)
- P2.1 (*Identify, prioritise and aggregate product requirements*)

- P2.2 (*Identify, prioritise and aggregate product resources*)
- P3.1 (*Identify, prioritise and aggregate production requirements*)
- P3.2 (*Identify, prioritise and aggregate production resources*)
- P4.1 (*Identify, prioritise and aggregate delivery requirements*)
- P4.2 (*Identify, prioritise and aggregate delivery resources*)
- P5.1 (*Identify, prioritise and aggregate RETURN requirements*)
- P5.2 (*Identify, prioritise and aggregate RETURN resources*)

The results generated by APP and RRP are then used by medium-term planning processes, namely the medium-term master production schedule (MPS) and the rough-cut capacity plan (RCCP) as discussed in Section 2.4.4.3. The MPS disaggregates the GIS unit's APP into the different GIS products that the GIS unit needs to produce and when these products should be available, taking into account existing and expected orders, and balances them with the unit's production capacity. The MPS also gives guidance on which spatial, related non-spatial and other data as well as GIS products need to be sourced by the GIS unit. The GIS unit could use the MPS to allow for ad hoc projects. This is done by splitting the planning horizon into two parts, namely a firm segment that allows the GIS unit to produce the committed GIS products at the allotted time periods as per existing orders and forecast needs, and a tentative segment that allows for the creation of ad hoc GIS products during the non-committed time periods. The size of the tentative segment is based on the forecast result of possible ad hoc projects that the GIS unit might have to do, drawing on past experiences. Based on the MPS, the RCCP looks at the availability of GIS and other staff to create the different GIS products in the specified time period to ensure that staff capacity is not over-stretched. In modelling and planning the GIS unit's supply chain using GDS, the MPS and RCCP information is managed by SCOR Level 3 enable planning processes EP.7. The information is used as input to the SCOR Level 3 process elements P2.1, P3.1, P4.1 and P5.1 (see Figure 5.9). MSP and RCCP feed into Material Requirement Planning (MRP) and Capacity Requirement Planning (CRP) respectively, which are used in the short-term operational planning processes. MRP is used to plan the production at the nuts-and-bolts level to meet the required demand.

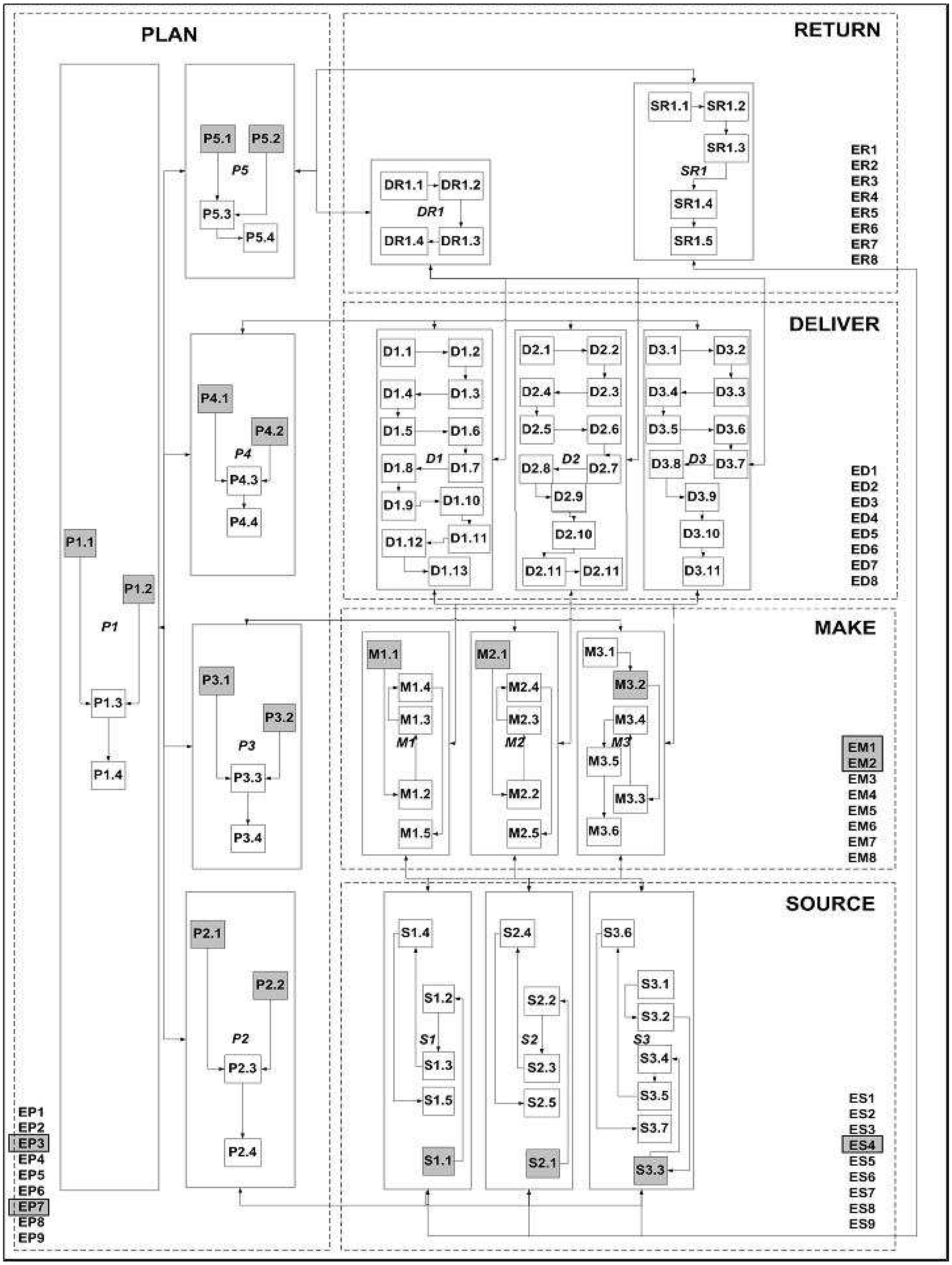

Figure 5.9: The enable processes and process elements involved in the operational plan of the supply chain

MRP in the context of GIS has been discussed in detail in Section 5.2.2. This section expands on the MRP concept in the context of creating GIS products. In Section 2.4.4.3 two concepts impact directly on an MRP, namely:

- Dependent and independent demand, where dependent demand is inventory used to create the planned GIS products base, expressed in a Bill of Materials (BOM), and independent demand which is governed by ad hoc requests made of the GIS unit.
- A BOM in the context of GIS is an inclusive list of all the required spatial, related non-spatial and other data, as well as GIS products required to create the different identified GIS products by the GIS unit. The BOM is used as an input into the SCOR Level 3 enable planning process EM.7 (*Manage planning configuration*).

Both information the MPS and BOM are used in the MRP to synchronise the availability of the required spatial, related non-spatial and other data as well as GIS products. Those data and GIS products that are not available will be sourced from suppliers at the appropriate times, which include proper lead times to ensure the timely arrival of the sourced data and GIS products. The MRP also schedules the timely release of data and GIS products from the data warehouse for the creation of the required GIS products by the GIS unit. As mentioned in Section 5.2.2, the MRP can be a simple spreadsheet indicating the necessary data and other GIS products needed to create a GIS product. The GIS unit can add to the spreadsheet, which is available from the data warehouse, those data and GIS products that need to be sourced and from whom and when as well as when the all the data and GIS products needs to be available in the data warehouse for the creation of the GIS product. Other information necessary on the MRP is the indication of the type of product that needs to be sourced based on the SCOR model, namely: S1 (**Source stocked product**), S2 (**Source Make-to-Order product**) and S3 (**Source Engineer-to-Order product**). The MRP provides input to the following SCOR Level 3 process elements, and enables production and sourcing processes:

- S1.1 (*Schedule product deliveries)*
- S2.1 (*Schedule product deliveries)*
- S3.3 (*Schedule product deliveries)*
- M1.1 (*Schedule production activities*)
- M2.1 (*Schedule production activities*)
- M3.2 (*Schedule production activities*)
- EM.1 (*Manage production rules*)
- EM.2 (*Manage production performance*)
- ES.4 (*Manage GIS products and data inventory*)

where M1 is **Make-to-Stock**, M2 is **Make-to-Order** and M3 is **Engineer-to-Order**. The Capacity Requirement Planning (CRP) uses information as specified in the MRP to determine the capacity required to create the GIS product using the spatial, related non-spatial and other data as well as GIS products. Section 2.4.4.3 gives three different process plans that can be used to enable the operations plan, namely: Just-in-Time (JIT), Quick Response (QR) and Efficient Consumer Response (ECR). The latter is not applicable to a GIS unit since it relates to the retail industry, which deals with fast consumer goods such as meat products and fresh produce.

In the GIS context it is suggested that Just-in-Time and Quick Response are appropriate processes to enable a GIS unit's operations plan. ECR was developed to provide efficiency in the retail industry, which falls outside the ambit of current GIS operations. Quick Response can be used by a GIS unit to handle ad hoc requests so as to allow it to deal quickly, effectively and efficiently with these requests. Quick Response in the GIS context relies on the GIS unit's ability to forecast possible ad hoc requests as well as a clear a brief as possible from the customer to the GIS unit to the unit to respond quickly to the request. The aim of the forecast in the context of Quick Response is to have the necessary data and GIS products available in the data warehouse. A clear brief from customers is necessary to eliminate the time and cost lost by trying to understand the exact need of the customer. The overall aim of Quick Response in the context of GIS is to minimise time, labour and cost to that which is absolutely necessary to create the GIS product.

Just-in-Time is used in longer-term GIS creation projects. As mentioned in Section 2.4.4.3, Just-in-Time works on the "pull" through the supply chain, i.e. spatial data, related non-spatial data and other data as well as GIS products are only requested from the suppliers and the data warehouse when needed. Just-in-Time eliminates unnecessary duplication of data or GIS products and the use of wrong versions of data or GIS products, and enables the data warehouse manager to manage the data warehouse in an effective and efficient manner.

Wisner, Leong and Tan (2005) indicated, as discussed in Section 2.4.4.3, that Just-in-Time consists of eight main elements. These elements can be applied in the context of GIS as follows:

- **Waste reduction**, which can include, as mentioned in Section 5.2.2, the removal of dead stock as well as the unnecessary movement of data and GIS products as discussed above.
- **JIT partnerships** are created between the GIS unit and its suppliers and customers to eliminate time wastage with regard to lead times during the sourcing of data and GIS products. Very long supply lead times by suppliers when ESI-GIS sources data is the biggest cause of time wastage by the GIS unit, and can result in the unit missing its project delivery deadlines (de la Rey, 2006).
- **JIT layouts** in the context GIS is the appropriate design of the data warehouse with regard to the location of spatial, related non-spatial and other data as well as GIS products. Proper design allows easy access to the different data and GIS products, thus eliminating or minimising time lost in searching for data.
- **JIT inventories** can be seen in the context of GIS as keeping only the necessary data and GIS products at the right locations in the data warehouse. This is closely linked with waste reduction and Just-in-Time layouts.

- **JIT scheduling** refers to having the data and GIS products available in the data warehouse for extraction during the GIS product creation as well as having the data warehouse configured to receive the completed GIS products from the GIS unit.
- **Continuous improvement** is achieved by fine tuning the GIS product supply chain using methods such as the SCOR model. It enables the GIS unit and its supply chain partners to identify and rectify problems much faster, and to apply quality control to received data and GIS products and to the GIS unit's own GIS products.
- **Workforce commitment** is entrenched by cross-training and continuous training, such as workshops and conferences, and empowering the staff to do their own problem identification, rectification and quality control of the GIS products they have created.
- **JIT II** is where a GIS unit places its own GIS staff at its customers' sites to act as buyers for the customer with regard to the unit's GIS products. They also assist the customer with installing the GIS product and provide GIS expertise to the customer. AfriGIS, a GIS company in South Africa, placed their own staff with the Independent Electoral Commission (IEC) to enable the IEC to track voting patterns and results and to display the results using a GIS[6].

This section examined the various operations and processes within a GIS product supply chain aimed at reducing cost, reducing inventory by eliminating redundant data from the data warehouse and improving the quality of the GIS products. The next section investigates quality management as part of supply chain management.

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[6] The author of this study participated in the 2006 municipal election as part of the election result forecasting team of the CSIR. The author did the spatial preparation for the forecast using GIS data from AfriGIS staff located at the IEC. Voting districts were depicted by re-allocating previous voting patterns from old voting districts to new demarcated voting districts.

5.4.4 Quality management within the GIS product supply chain

Supply chain management aims to create an efficient and effective supply chain with the aim of reducing the cost and improving the profitability for each supply chain member, as well as to improve the quality of the products and services delivered. The Total Quality Management (TQM) technique, as discussed in Section 2.4.4.4, is used to ensure the quality of the completed end products. The same approach can be used in the GIS product supply chain to improve the quality of the GIS products that are produced by a GIS unit. TQM is closely linked with Just-in-Time as discussed in the previous section, and includes both the GIS unit's suppliers and customers. TQM has its focus on the customer and it involves the complete workforce, i.e. in the GIS context from top management of the organisation, if the GIS unit is part of an organisation, to the GIS staff and support personnel internal and external to the GIS unit.

Several approaches to implement TQM in a company and the supply chain as a whole have been elaborated upon in Section 2.4.4.4, which are listed below:

- Six Sigma
- Deming's way
- Crosby's way
- Juran's way
- The Malcolm Baldridge National Quality Award
- International standards: ISO.

In addition to the ISO 9000 suite of standards, ISO developed a suite of standards for GIS, namely the 19100 suite of standards as discussed in Section 3.4.5.3 and Appendix A, and the management of the standards compliance discussed in Section 4.3.2.9. The following tools were mentioned in Section 2.4.4.4 that can be used to implement and run TQM:

- Flow diagrams
- Check charts
- Pareto charts

- Cause-and-effect diagrams
- Statistical process control.

Using SCOR to model the GIS unit supply chain enables the GIS unit to map the GIS product creation process using the five management processes (**PLAN**, **SOURCE**, **MAKE**, **DELIVER** and **RETURN**) as well as their related process categories, process elements and enable process elements. Using the different metrics as given for each SCOR Level 3 process element and enable process, the GIS unit can determine problem areas within the supply chain and correct them using the recorded best practices and features as guidelines as discussed in Section 5.2.

The advantage of using SCOR in the context of this study is that it enables the GIS unit to add best practices to each process element and enable process as the unit uses SCOR over time, thus improving the supply chain and the quality of the GIS product on a continuous basis. In the SCOR model as highlighted in Figure 5.10, the following enable process elements concentrate specifically on standards and other regulatory requirements which aim to improve the quality of the GIS product, namely:

- EP.8 (*Manage PLAN regulatory requirements*)
- EM.8 (*Manage MAKE regulatory requirements*)
- ER.8 (*Manage RETURN regulatory requirements*).

As part of modelling the GIS product supply chain at the management process level (SCOR Level 1), cause-and-effect (fishbone) diagrams are used based on the process as presented by Bolstorff and Rosenbaum (2003) to determine different problems and their causes with regard to the creation of GIS products. Cause-and-effect diagrams start with the problem that was identified in the form of a problem statement, which is shown at the head of the "fish" (see Figure 5.11). The bones of the "fish" consist of the various causes and sub-causes of the problem. By addressing the various causes and sub-causes, the problem will be solved over a specified time. The results of these diagrams are used in determining problems at SCOR Level 3 process mapping.

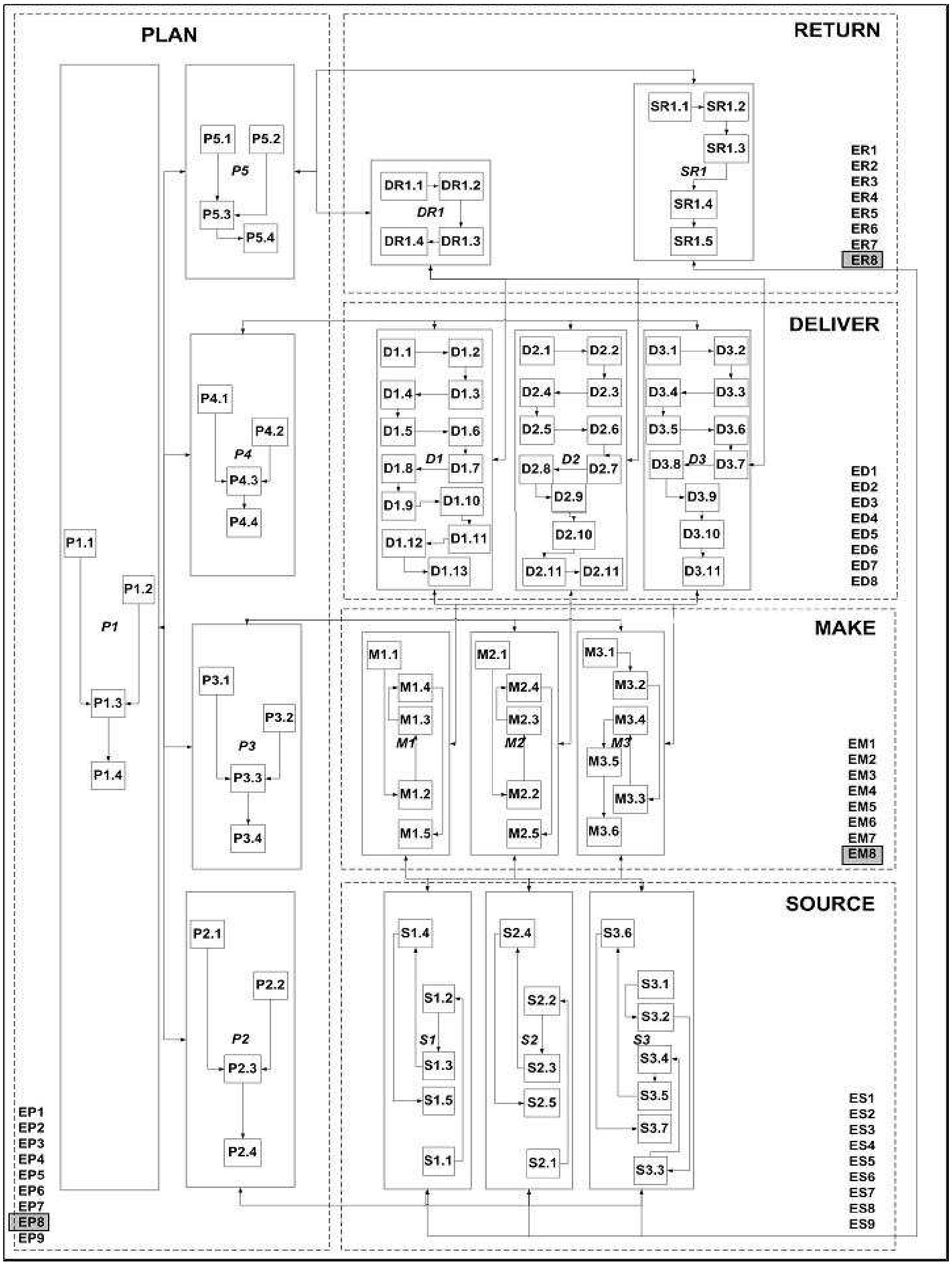

Figure 5.10: The enable processes involved in the quality management of GIS products

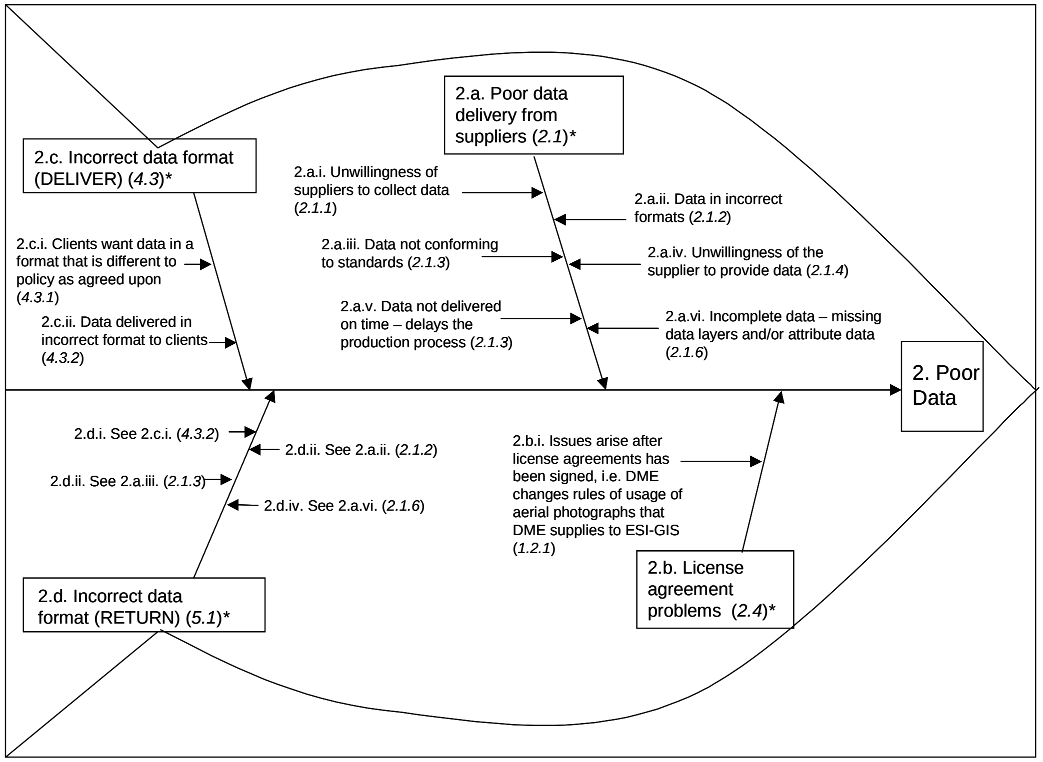

Figure 5.11: An example of a cause-and-effect diagram with regard to the causes of poor data at a GIS unit

Other tools that can be used by the GIS unit to assist with the implementation and running of TQM are check lists to list possible problems that can be encountered during the GIS product creation process. The Pareto charts are used to rank existing problems and then those with the biggest impact are rectified first by using the Pareto principle. The last tool is statistical process control as discussed in Wisner, Leong and Tan (2005: 229-236). Workflows at the detailed production level can be used to improve the quality of the finished GIS product as discussed in Section 4.4.

This section discussed operational issues in the supply chain which ranged from forecasting, operations planning to quality management. Under forecasting, the customer's future needs are determined which in turn influence the production of GIS products.

To enable production, operational planning must be done. Operations are planned on the basis of three-time horizons, namely the long, medium and short term, known as the aggregate production plan. It guides the master production schedule which in turn guides the materials requirement plan. Production must be quality controlled and the method used is total quality management. To enable the GIS unit to utilise the above to the fullest, it needs marketing. Marketing is based on the customer's needs as forecast, but marketing goes beyond that, since it influences the supply chain, the kind of suppliers needed to fulfil the materials requirement plan, the quality of the product and customer satisfaction. The marketing of GIS products is examined in more detail in the next section.

5.5 Marketing

According to Min (2001) as mentioned in Section 2.4.5, a market is defined as a collection of buyers and sellers. In this instance the sellers will be GIS units that sell GIS products and the buyers will be other GIS units, organisations and institutions that are buying the GIS products if certain conditions are met.

Marketing as discussed in Section 2.4.5 is given as a business philosophy, which is known as the marketing concept and which is based on the following three pillars, namely:

- Customer focus, where the GIS unit determines and responds to the internal and external customers' needs either through forecasting as discussed in Section 5.4.2 or through its customer-supplier relationship using tools such as Collaborative Planning, Forecasting and Replenishment as described in Section 5.4.2.
- Coordinated marketing, in which the staff of the GIS unit act as marketers in conjunction with either an internal or outsourced marketing division to respond to the needs of the customers. The marketing division in general does the hardcore marketing of the GIS unit and its GIS products by setting up exhibitions at trade fairs such as INTERGEO (Europe's largest conference and trade fair for geodesy, geoinformation and land

management), promotions or by placing advertisements in business or trade magazines as shown in Figures 5.12 and 5.13. Figure 5.12 shows an advertisement for OSNI (Ordinance Survey Northern Ireland) road centreline data in the December 2006 issue of GEOInformatics. Figure 5.13 shows an advertisement for ESI-GIS products and services published in the September/October 2006 issue of PositionIT, a journal which provides information on geoinformatics and surveying for Southern Africa. The staff of the GIS unit does the informal marketing by creating a reputation of delivering the right GIS product on time and to the right customer within the quoted budget and by attending workshops and conferences.

- Profitability: The GIS unit aims to keep marketing costs as low as possible and sales as high as possible.

Figure 5.12: OSNI GIS product advertisement in GEOInformatics
(from GEOInformatics, 2006)

The above will guide the GIS unit's generation of market intelligence, the dissemination of the market intelligence throughout the unit and the supply chain and the response to the received market intelligence via the aggregated production plan, master production schedule, materials requirement plan, related resources management (Section 5.3.3) and total quality management (Section 5.3.4). These activities will lead to the improvement of the supply chain to meet the customers' demands effectively and efficiently. The required improvement of the supply chain is made using relationship marketing concepts in which the GIS unit establishes, maintains and enhances supply chain relationships with its suppliers and customers. Section 2.4.5 gives an in-depth discussion on relationship marketing.

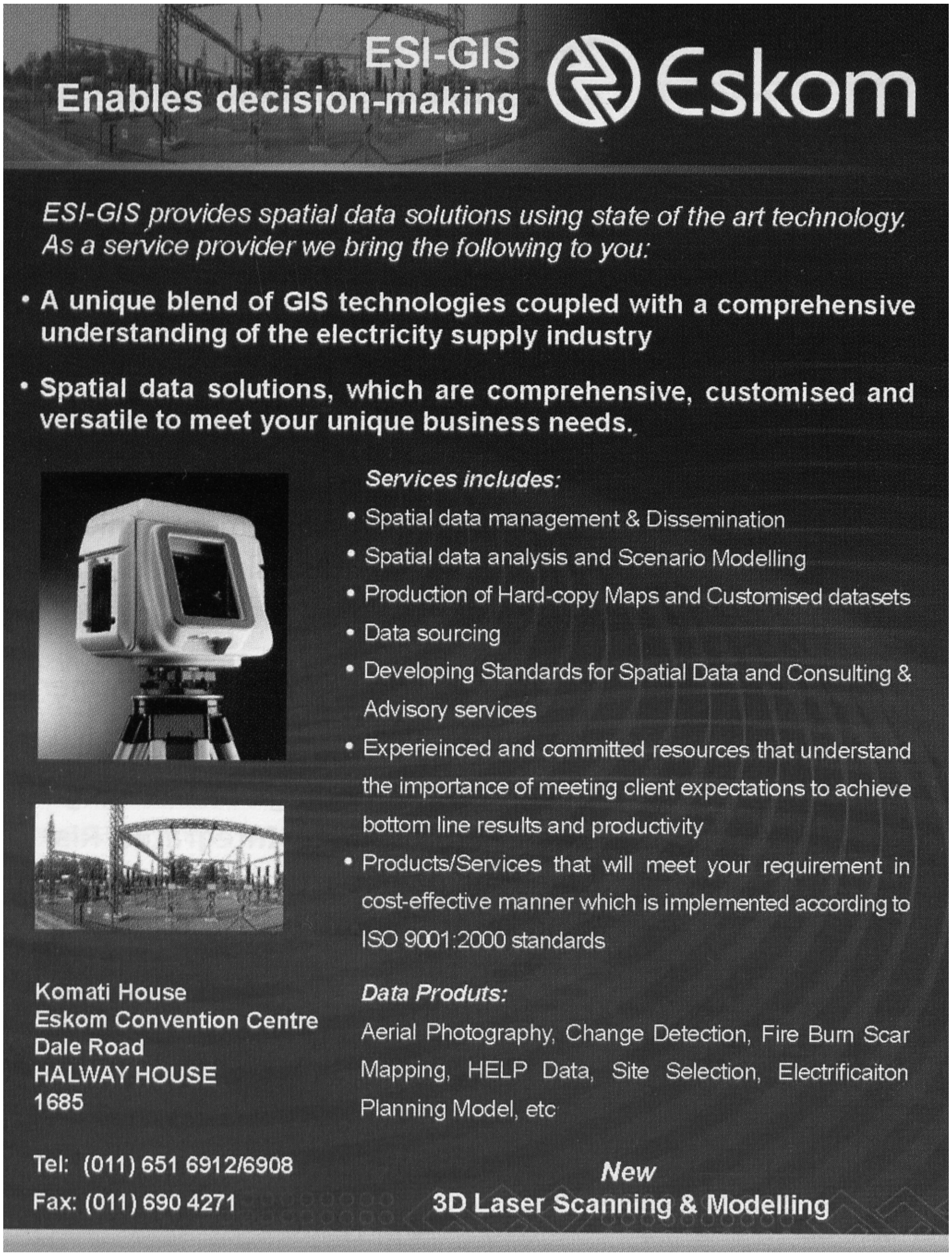

Figure 5.13: ESI-GIS advertisement in PositionIT

(from PositionIT, September/October 2006)

5.6 Third-Party logistics

The end result of marketing as discussed in the previous section will lead to the movement of spatial, related non-spatial and other data as well as GIS products up and down the supply chain. Various modes of moving data and GIS products have been discussed in Sections 5.2.3 and 5.3.4. Section 2.4.6 discusses the concept of third-party logistics (3PL) in which firms outsource their logistic requirements fully or partially to outside organisations known as 3PL service providers such as DHL, FedEx or Uti. In the context of GIS, 3PLs are restricted to courier companies that transport the data and GIS products up and down the GIS product supply chain and organisations that offer GIS Web services to the supply chain.

GIS Web services, according to Tang and Selwood (2003), are organisations that provide spatial, related non-spatial and other data, as well as GIS products and GIS functionality over the World Wide Web, which allows GIS units to integrate the above without having to host their own functionalities, data and GIS products. Organisations that offer GIS Web services are not restricted to providing services in their own countries, but could supply services to GIS units in other countries as well, which leads to the concept of global supply chains for GIS products. Global supply chains are discussed in the next section. 3PL activities are managed at SCOR Level 3 by the following enable processes (see Figure 5.14):

- EP.6 (*Manage integrated supply chain transport*)
- ES.6 (*Manage incoming product*)
- EM.6 (*Mange transportation (WIP)*)
- ED.6 (*Manage transportation*)
- ER.6 (*Manage return transportation*).

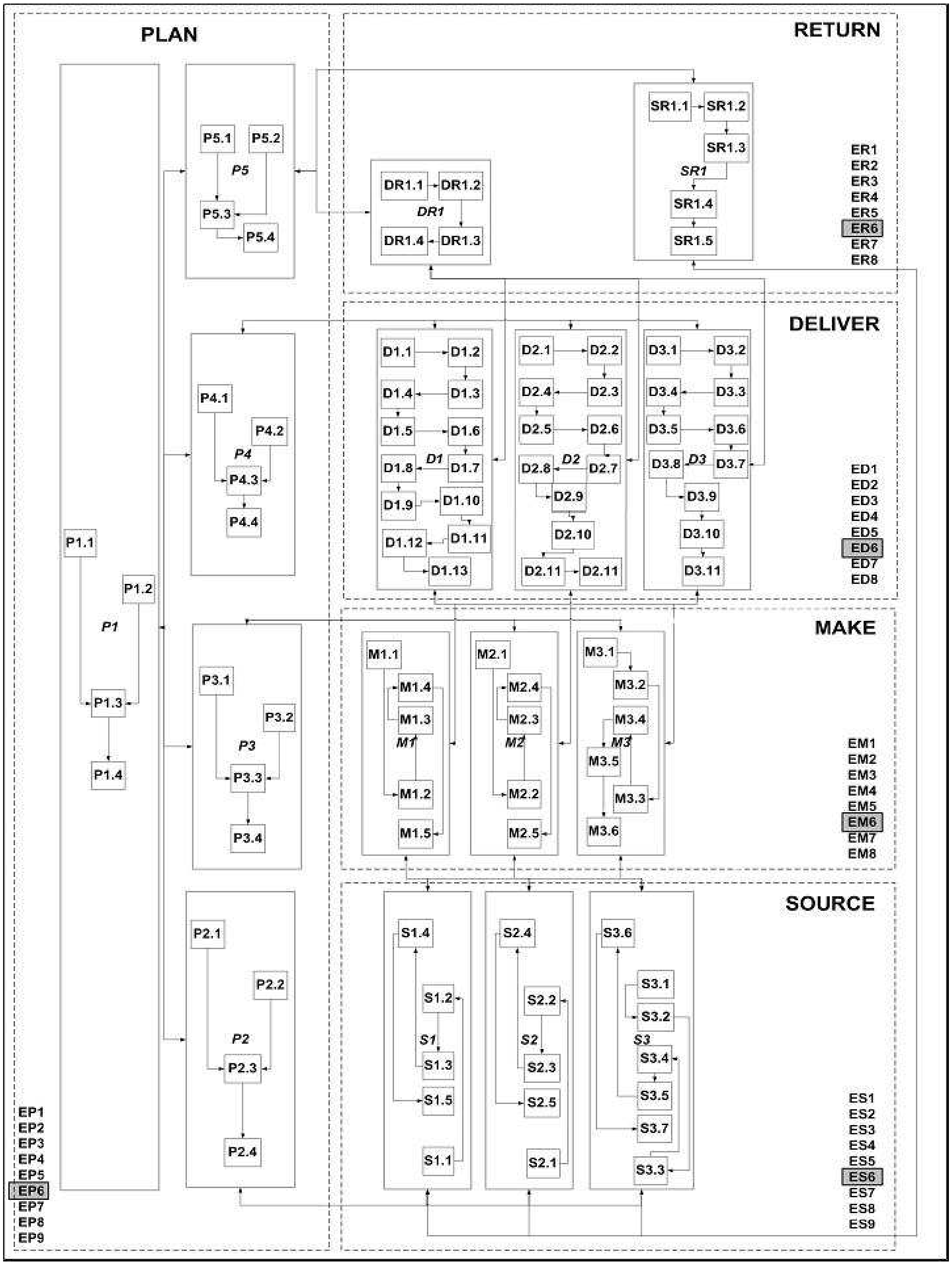

Figure 5.14: Enabling processes that manage 3PL activities within the supply chain

5.7 Global supply chains

An overview and examples of global supply chains are given in Section 2.4.7 as well as the creation of regional trading blocks and their effect on the global supply chain. This section examines the possibilities of a global supply chain for GIS products.

Organisations that offer GIS Web services as mentioned in the previous section could be part of a global supply chain if they are located in a different country than the country of the GIS unit making use of their services. The acquisition of satellite imagery by GIS units can be seen as having elements of a global supply chain. If the country in which the GIS unit is located does not have the facility to acquire an image directly from a satellite when the satellite is within the ground station's range, then it must order the image from the organisation that operates the satellite. The GIS unit can order the satellite imagery directly from or through an agency representing the organisation. With respect to GIS units in South Africa, these organisations are situated in Canada, Europe, India, Japan, Russia and the USA.

As an example, Figure 5.15 shows the global supply chain for a GIS unit in South Africa utilising QuickBird satellite imagery which is operated by Digital Globe. The sourcing of the QuickBird image is as follows (Eloff, 2007):

- The GIS unit places an order with the Satellite Applications Centre (SAC) at Hartebeeshoek, giving information on the area that needs to be covered and the time of image acquisition (archived or new acquisition). Archived acquisitions are images that have been archived since 2005, and that can be extracted upon request (for the GIS unit the SCOR Level 2 process will be S1: **Source Stocked Product**), whereas for a new acquisition the satellite needs to be programmed to acquire the image during the next overpass (S2: **Source Make-to-Order Product**).
- If a new acquisition is required, the SAC places an order with *MAPS geosystems*, a GIS unit in the United Arab Emirates (UAE), which is the designated distributor for Digital Globe, the operators of the QuickBird

satellite. Appendix B gives an example of an order form from *MAPS geosystems* which is used to place an order online.

- *MAPS geosystems* in turn places an order with Digital Globe based on the information received on the order from the SAC, and Digital Globe then programs the satellite to acquire the image and sends the acquired image to *MAPS geosystems*.
- *MAPS geosystems* then sends the acquired image on a DVD (as stated on the order by the SAC) by courier to the SAC.
- The SAC then sends the DVD to the GIS unit which placed the order with the SAC.

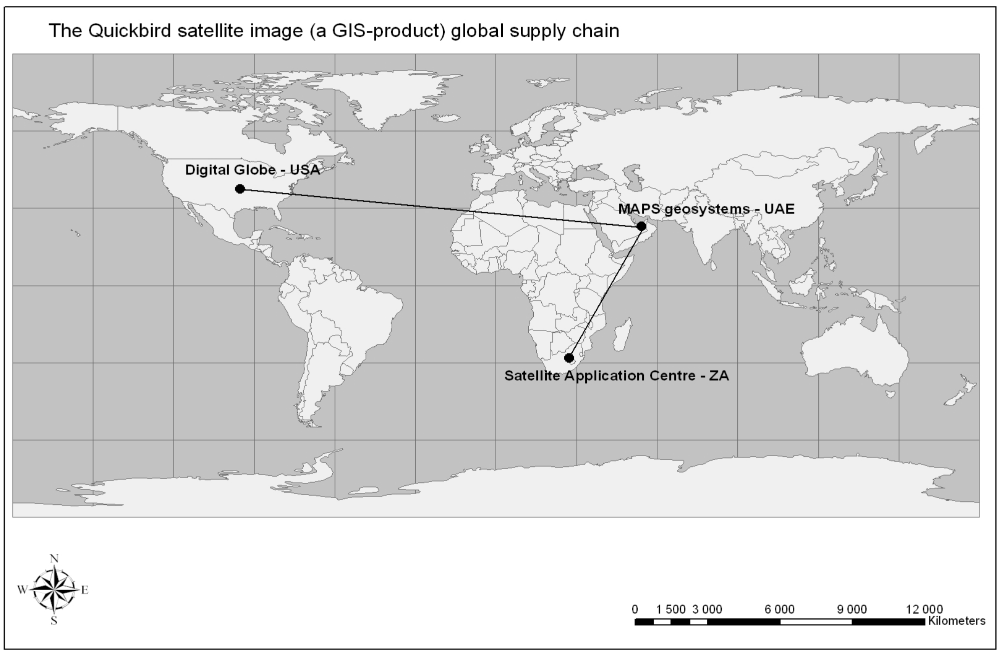

Figure 5.15: The QuickBird satellite imagery global supply chain

Since the satellite image is imported from another country, the GIS unit has to pay custom duties. According to Eloff (2007), the custom duties in South Africa are levied on the medium used, such as DVDs and removable hard disks, and not the data itself. If a DVD is used as a medium the customs duty is approximately seven US dollars per DVD (Eloff, 2007). The management of import and export requirements of the supply chain using the SCOR model for sourcing GIS products at SCOR Level 3 is ES.8 (*Manage import/export requirements*).

The acquisition of a new QuickBird satellite image is time consuming since it is dependent on the location of the QuickBird satellite in relation to the area to be acquired. It can take tens of days before the satellite overpasses the area in question. QuickBird has an optical sensor which is influenced by weather, which means if unfavourable weather conditions are prevalent during the overpass, the acquisition of an image of the area will have to be held over until the next overpass by the satellite (Eloff, 2007).

The challenge to the GIS unit is to improve the global supply chain by shortening the supply chain and/or improving lead times. Owing to the methodology of acquisition and the risks involved, improving the lead times for image acquisition is not possible, except for sending the data via the World Wide Web instead of transporting DVDs via a courier. The cost saving would lie in shortening the supply chain by excluding the intermediate players, namely the SAC and/or *MAPS geosystems*. The ideal supply chain for satellite imagery acquisition in South Africa would be direct acquisition of satellite imagery by the SAC, which would then deliver the image directly to GIS unit. The SCOR Level 2 process category for the GIS unit will be S2 (**Source Make-to-Order Product**). Currently the SAC directly acquires images from the following satellites (Eloff, 2007):

- SPOT 2, 4 and 5
- MODIS
- NOAA
- ERS
- EROS A1
- Landsat 5.

The risks to a GIS product global supply chain as described above, which need to be managed, are satellite loss, currency fluctuations, sudden political instability or economic sanctions imposed by the host country of the satellite operator or a combination thereof. Section 2.4.7.5 discusses different strategies a GIS unit can follow to manage the abovementioned risks. Global supply chains, as mentioned in Section 2.4.7.5, are dependent on information and communications technology (ICT) to function optimally. The role of ICT in GIS product supply chains will be discussed next.

5.8 The role of information and communications technology (ICT) in supply chains

Information and communications technology (ICT) plays an important role in GIS. It provides the GIS product supply chain with the necessary connection between the supply chain members upstream and downstream of the supply chain as discussed in Section 2.4.8, and it provides the means to move spatial, related non-spatial and other data as well as GIS products between the supply chain members. Fisher (2006) indicated that at the INTERGEO 2006 trade fair there was a strong emphasis on GIS Web-based services that will lead to the construction of regional, national and international spatial data infrastructures. GIS Web portals and GIS Web-based services will be heavily reliant on good-quality ICT infrastructures. GIS portals, GIS Web services and Geography Networks have been discussed in Sections 3.2.5 and 5.7.

Some GIS units such as Ordinance Survey Northern Ireland (OSNI) already have e-Commerce capabilities in place to enable other GIS units to order OSNI GIS products online and to pay for these products online. Figure 5.16 shows OSNI's Web site which has an e-Commerce facility with shopping cart and check-out icons.

ICT plays an important role in supply chain activities. Looking at SCOR Level 3 process elements, as illustrated in Figure 5.17, ICT is used to communicate the different supply chain plans created in the different **PLAN** processes, such as P1.4 (*Establish and communicate supply chain plans*), P2.4 (*Establish sourcing plans*), P3.4 (*Establish production plans*), P4.4 (*Establish delivery plans*) or P5.4 (*Establish and communicate Return plans*). ICT is used in the **SOURCE** management process when sourcing and scheduling the delivery of the different spatial, related non-spatial and other data as well as GIS products from suppliers by sending a procurement signal using telephone, fax, Internet or e-Commerce (S1.1, S2.1 and S3.3).

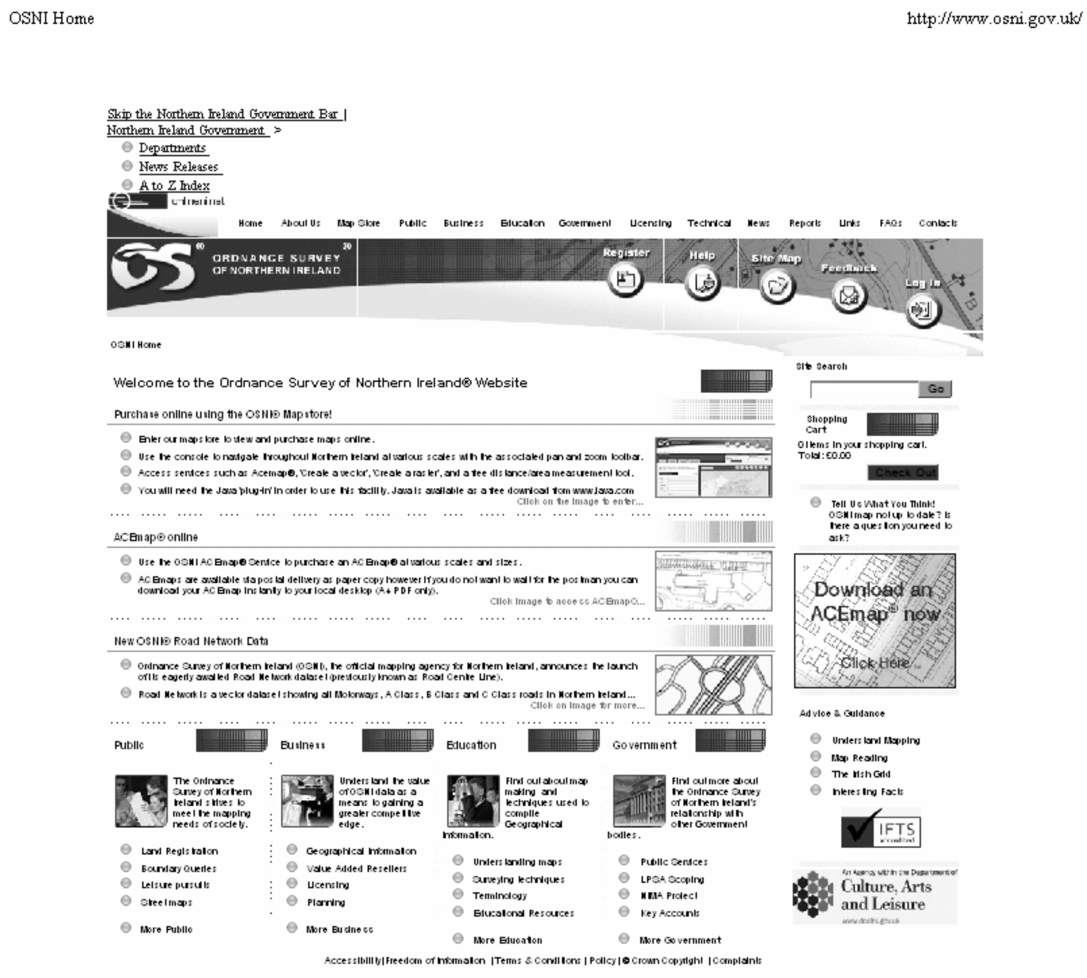

Figure 5.16: OSNI Web site with e-Commerce capabilities (OSNI, 2007)

(from http://www.osni.gov.uk)

The authorisation of payments and the actual payments are done using ICT. The authorisation can be sent via e-mail and the payment is mad using Internet banking facilities. The data and GIS products are moved from the suppliers to a data warehouse using ICT (Sections 5.3.3 and 5.4.4), for which the SCOR Level 3 process elements are S1.4, S2.4 and S3.6.

ICT is also used in the **MAKE** management processes, namely the scheduling of production activities (M1.1, M2.1, M3.2 and M4.1). The issuing of data and GIS products (material) from the data warehouse to the different assigned work stations for the creation of the GIS product is facilitated by, for example, using the GIS unit's LAN (M1.2, M2.2 M3.3 and M4.2).

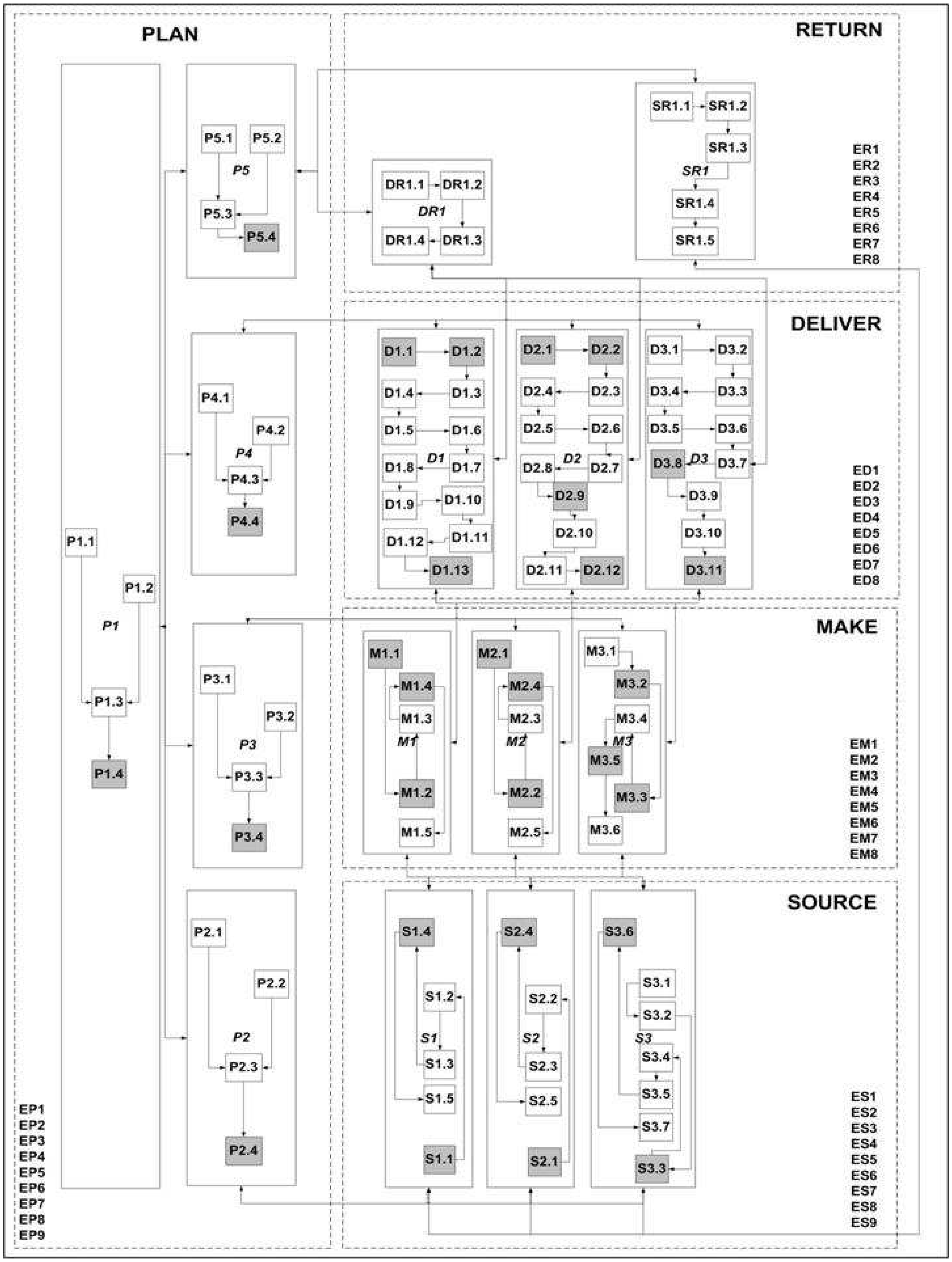

Figure 5.17: Process elements that are reliant on ICT

The completed GIS product is transferred to the data warehouse using ICT infrastructure (M1.4, M2.4 and M3.5). Once the created GIS product has been transferred to the data warehouse, a GIS product release signal is sent to enable the GIS unit to deliver the GIS product to the customer.

ICT is used throughout the **DELIVER** management process, which ranges from inquiries to orders from customers, e.g. D1.1 (*Process inquiry and quote*) and D1.2 (*Receive, enter and validate order*). If ICT is used to ship the GIS product (see Sections 5.2.3 and 5.2.4), an example of the relevant SCOR Level 3 process element is D2.9 (*Generate shipment documentation, verify credit and ship GIS product*). Invoicing the customer and the receipt of payment from the customer is mostly done using one form of ICT or another, such as the Internet. An example of the SCOR Level 3 process element would be D3.11 (*Invoice and receive payment*). ICT is also used when returning (**RETURN**) defective GIS products or data to the GIS unit from its customers or to the GIS unit's suppliers. From the above it is clear that ICT plays a very important role in the creation of a GIS product and its supply chain.

5.9 Conclusions

This chapter discussed supply chains and supply chain management in the context of GIS using the SCOR model as a guide. The SCOR model is used for the first field study in this research. The above discussions clearly illustrate that the orders that a GIS unit receives for a GIS product need to be managed properly to ensure that the customer receives the right GIS product. Inventory in the form of various spatial and non-spatial datasets need to be managed properly to ensure that the correct datasets are accessible, and one such entity in which the inventory can be kept is a data warehouse. Transport of the various datasets from the suppliers to the GIS unit and from the GIS unit to the customers need to be managed properly to ensure that the GIS unit receives the datasets on time and delivers them at the right time to the customer. The establishment of networks ensures a leaner supply chain and needs to be managed as such.

Materials management includes the management of the procurement process, data warehousing and production planning, including the various spatial and non-spatial layers required, inbound transportation and receiving of the various datasets as well as other software and hardware needed to create a GIS product.

Operations management ensures that the GIS unit creates the right product for the right customer at the right time. for the ability of a GIS unit to forecast its customers' needs is seen as an essential operations activity to enable a GIS to respond timeously to its customers needs as indicated by Dangermond (1999) and Tomlinson (2000) in Section 1.1. Based on a well-managed forecasting activity, the GIS unit is then able to do operations planning for the long, medium and short term to ensure that the GIS delivers the right GIS products to right customer. Quality management is an operations management activity that guarantees that the GIS unit will deliver a GIS product to its customer's satisfaction.

A GIS unit can have the above management processes in place, but if it does not market itself, all these activities will be in vain. There are various avenues available to GIS unit to market itself as illustrated in Section 5.5. Third-party logistics is mostly restricted to courier services. Owing to the nature of certain spatial datasets such as satellite imagery, a GIS unit needs to establish a global supply chain to acquire the relevant data, which must be managed properly to ensure that the GIS unit receives the data on time. Proper ICT management is necessary since GIS is in the domain of ICT, i.e. it is a Geographic Information System, as well as making use of ICT to transport datasets and software. A further aspect is that some GIS units are now using e-Commerce for their business activities.

From these discussions it is concluded that the creation of GIS products by a GIS unit can clearly be defined as a supply chain, and that this chain needs to be managed using supply chain management. This chapter clearly realises objective D: **Can supply chain management be linked to GIS in order to become a management tool for GIS?** It does not, however, achieve objective E: **Can supply chain management be used to successfully manage the production of GIS products by a selected GIS (ESI-GIS)?** Before an answer to the objective can be found, it is necessary to discuss the GIS unit that will be used for the field research. The selected GIS unit is discussed in the next chapter.

Chapter 6: Geographical Information System of the Electricity Supply Industry

6.1 Introduction

Chapters 2, 3 and 4 discussed supply chains, supply chain management, Geographic Information Systems (GIS) and the management of GIS in detail. Chapter 4 shows that the management of GIS is done on a holistic level from implementation to operational management, and on a project level where GIS projects are managed using standard project management procedures and workflow to automate certain processes and to manage projects. These chapters also realised objectives A, B and C that were formulated in Section 1.5. By achieving objective D, Chapter 5 illustrated that it is possible to use supply chains in the creation of a GIS product and that these chains can be managed by a GIS unit using supply chain management.

It was indicated that in order to realise objective E, it was necessary first to discuss the GIS unit that is used to demonstrate the use of supply chains and supply chain management by a GIS unit as stated in Section 1.5. The selected GIS unit is the **E**lectricity **S**upply **I**ndustry **G**eographical **I**nformation **S**ystem (ESI-GIS) unit within the Distribution Business Support division of Eskom which was formed in 2002. This came about because of the Department of Minerals and Energy (DME) appointed the Eskom Distribution Group as the principal agent to provide a geospatial information service to the DME. ESI-GIS also provides the same service to the Eskom Group and to other interested parties. Their service ranges from establishing and maintaining spatial information on electricity distribution to the development of scenarios and simulation models to assist in electrification planning (Schmitz, 2005).

This chapter first discusses the strategic background of the GIS unit, with an overview on the GIS unit's reason for existence, critical success factors of ESI-GIS, ESI-GIS's critical business issues and a Strength, Weaknesses, Opportunities and Threats (SWOT) analysis of ESI-GIS. Secondly, this chapter discusses the financial performance of ESI-GIS, and thirdly, it discusses the internal and external profile of ESI-GIS. Figure 6.1 shows the location of ESI-GIS at the Eskom Convention Centre as well as the regional offices to which ESI-GIS provides a service.

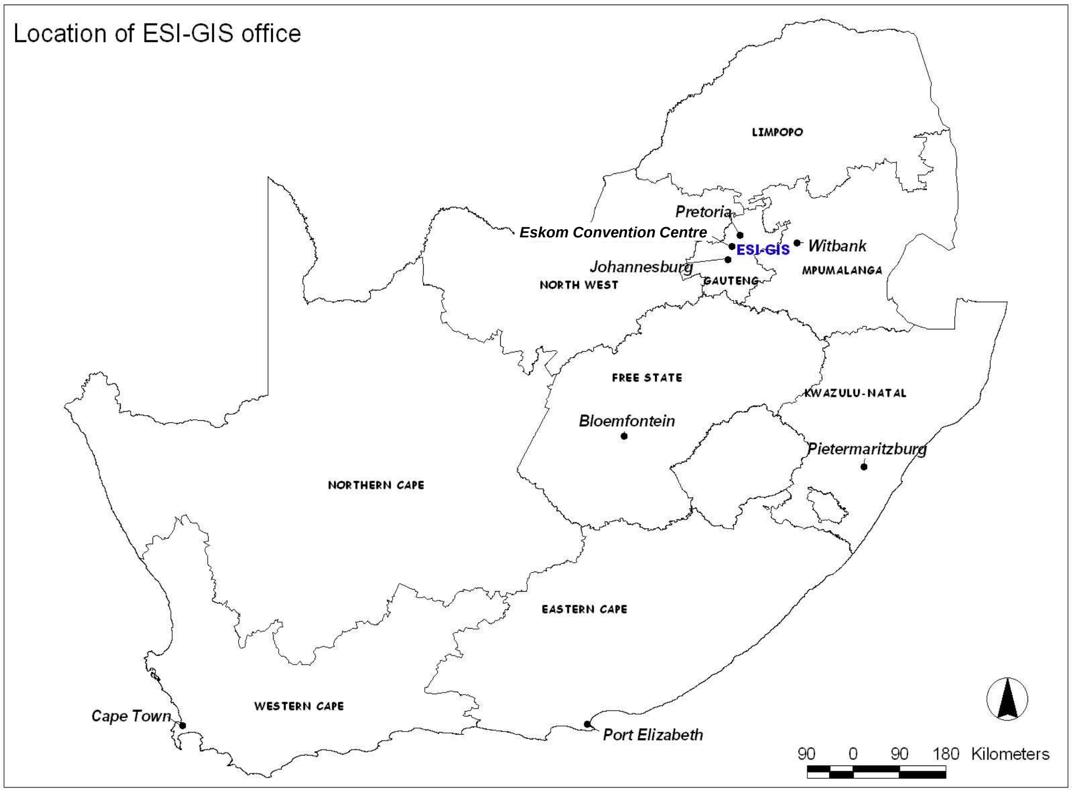

Figure 6.1: Location of ESI-GIS and Eskom's regional offices
(from de la Rey, 2005)

6.2 Strategic background of the GIS unit

This section examines the strategic background of ESI-GIS, starting with a business description of ESI-GIS.

6.2.1 Business description

The **E**lectricity **S**upply **I**ndustry **G**eographical **I**nformation **S**ystem (ESI-GIS) Unit was relocated from Eskom Distribution to the Resources and Strategy division in 2005. ESI-GIS provides GIS integration, core or common data sets and decision-making services to the Eskom Group, as well as to other interested parties. The service ranges from establishing and maintaining spatial information on the electricity distribution to the development of scenarios and simulation models to assist in electrification planning (De la Rey, 2006).

6.2.2 Value proposition of ESI-GIS

The value proposition of a GIS unit is the description of the GIS unit from the customer's point of view. Common requirements according to Bolstorff and Rosenbaum (2003:27) are: price, product quality, technical innovation, customised packaging, delivery reliability, order lead time, strategic relationships and value-added services. The ESI-GIS value proposition is:

> *"ESI-GIS is regarded as the leading provider of spatial information solutions in the Southern Africa electricity supply industry. Our thorough understanding of the market provides us with the opportunity to align our services with the technological demands being made by the industry. We are in the forefront of geospatial information solutions by providing unique products and services on time that satisfy customer needs"* (ESI-GIS, 2006a).

6.2.3 Critical success factors of ESI-GIS

Based on the above value proposition. the following are seen as the critical success factors of ESI-GIS (De la Rey, 2006):

- ESI-GIS has the ability to support the geospatial needs of the Southern African electricity supply industry.
- ESI-GIS has the skilled and experienced manpower to provide the required support.
- ESI-GIS has extensive spatial data on electricity networks and provision in Southern Africa as well as other related spatial data sets , which forms the basis of the required support.

- ESI-GIS has a policy of strict adherence to geospatial and other relevant ISO, SANS and in-house standards. ESI-GIS is an ISO 9001-certified organisation.
- ESI-GIS keeps up with the latest technological advances so as to provide a superior service, such as a 3D laser scanner that is used to map substations.
- ESI-GIS is willing to transfer skills where required.

6.2.4 Critical business issues

The following critical business issues below are regarded by ESI-GIS as having a negative impact on its day-to-day business.

- The quality of data provided by national custodians.
- The role and mandate of ESI-GIS is not fully clarified with its stakeholders and customers.
- The availability of skilled resources in the GIS market.
- Insufficient funding for research and development.
- The need to build marketing capabilities to increase the customer base.
- More experienced and skilled resources are needed to provide specialised services.
- Improved service levels from support functions (i.e. human resources (improved), information technology, procurement, etc. are needed.
- There is a lack of project management experience (ESI-GIS has shown an improvement in project management, but this still needs further development).
- There is currently no server for data warehousing.

6.2.5 SWOT analysis

The SWOT (Strength, Weaknesses, Opportunities and Threats) model is used to get a quick understanding of the health of a business unit or an organisation looked at internally (strengths and weaknesses) and externally (opportunities and threats). The initial SWOT analysis was done by Arivia.kom, a commercial stateowned enterprise information technology (IT) professional service provider which provides integrated business solutions, and Eskom distribution in 2003 (Salojee and De la Rey, 2003). The current SWOT analysis was based on the initial SWOT analysis and adjusted in 2006 to reflect the current status of ESI-GIS. The results of the SWOT analysis are used to review the current strategy and to develop a new strategy to improve the business (Marketing Teacher, 2006; Businessballs.com, 2006 and Mind Tools, 2006). ESI-GIS's SWOT analysis results are given below:

6.2.5.1 Strengths

- Infrastructure is in place (software, hardware, data sets).
- Skills/competency base is in place (qualified and experienced personnel).
- ESI-GIS has enough funds to keep itself sustainable.
- ESI-GIS is customer-focused and driven.
- ESI-GIS keeps to deadlines.
- It has very good team dynamics.
- It is the only unit of its kind in South Africa in a specialist field with high marketability.
- ESI-GIS has a good record of accomplishment.
- It has improved in-house specialist skills.
- ESI-GIS has a formal mentorship programme.

6.2.5.2 Weaknesses

- Lack of communications within the team, which results in duplication
- Team motivation is not at an acceptable level
- Lack of discipline
- Lack of vision
- Inefficient procurement process, including human resources
- Lack of possibility to employ additional skilled resources.

6.2.5.3 Opportunities

- Provide external training in order to build up a better resource base.
- Expansion of the customer base, especially within the Eskom Group.
- The provision of services for demand trends, especially electricity supply entities that do not have GIS units, such as stated in Eskom's universal access plan for 2012/13, which aims to provide access to electricity for every household in South Africa, and is based on the State of the Nation address by President Thabo Mbeki in 2004.
- To become a strategic unit in the Eskom Group which can provide decision-making based on spatial modelling support.
- To become the Eskom Group's spatial data custodian according to the SDI Act (Spatial Data Infrastructure Act of 2003).
- ESI-GIS has the capability to grow internally.
- 3D data collection and manipulation.
- Research and development opportunities using GIS and related technologies.
- The application of satellite imagery as a business tool in the Eskom Group.

6.2.5.4 Threats

- Low data integrity from suppliers and ESI-GIS itself due to quality from suppliers.
- Competition from other GIS organisations such as consulting firms.
- Inefficient procurement processes delay project deliverables, which could result in a loss of clients.

6.3 Financial performance of the GIS unit

Table 6.1 gives the financial statements of ESI-GIS since 2003. In 2003 and 2004 the unit received most of its funds from the Department of Minerals and Energy (DME) as explained in Section 6.1. In 2004 the DME established its own GIS unit, which resulted in a reduced involvement between the DME and ESI-GIS since 2005 (De la Rey, 2006). ESI-GIS showed a good profit in 2005

(R540 724.45), but in 2006 the financial model for ESI-GIS changed from a business unit that must make a profit to a unit that is a corporate overhead. Any losses that ESI-GIS incurs are covered by corporate strategic overheads. The high expenditure in the financial statement for 2006 includes the purchase of a 3D laser scanner that cost close to R2 million. The other costs were mostly for data including SPOT 5 satellite imagery, specialised spatial data sets from other GIS companies such as Geospace and Alex Fortescue, and electronic data from the Chief Directorate: Surveys and Mapping (De la Rey, 2007). The high loss (R4 300 100) is due to non-payment for work done for the DME (R1 310 000), ad hoc requests (R938 185), and Eskom itself (R2 051 915).

Table 6.1: Financial statements of ESI-GIS

	2003	2004	2005	2006
Income				
DME	R 8 144 653.00	R 7 661 600.00	R 0.00	R 0.00
Eskom	R 0.00	R 353 000.00	R 6 596 000.00	R 4 466 448.89
SLA				R 960 000.00
Other	R 0.00	R 0.00	R 0.00	R 6 931 958.00
Subtotal	R 8 144 653.00	R 8 014 600.00	R 6 596 000.00	R 12 358 406.89
Expenditure				
Manpower	R 1 890 000.00	R 2 200 000.00	R 3 330 844.00	R 2 796 757.45
Materials	R 2 901.00	R 23 000.00	R 0.00	R 13 067 769.07
Internal charges	R 183 000.00	R 196 000.00	R 598 800.00	R 109 660.08
External Services	R 0.00	R 0.00	R 87 000.00	R 0.00
General expenses	R 268 752.00	R 206 000.00	R 2 005 606.50	R 684 319.86
Depreciation	R 0.00	R 0.00	R 33 025.05	R 0.00
Contracts	R 5 800 000.00	R 5 500 000.00	R 0.00	R 0.00
Subtotal	R 8 144 653.00	R 8 125 000.00	R 6 055 275.55	R 16 658 506.46
Total	R 0.00	-R 110 400.00	R 540 724.45	-R 4 300 099.57

Comments

2003 and 2004: No data available on depreciation
2004: Deficit due to non-payment by DME
2006: Materials included in General Expenses
2005 and 2006: Contracts included with General Expenses
2004 and 2005: External Services part of General Expenses
2006: Any Net Loss will be covered by Corparate Strategic Overheads
ESI-GIS will start each year with R0.00
From 2004 DME established their own GIS unit
2006: Total other manpower included in general expenses
2006: Materials = Consulting fees, including external services

6.4 Internal profile of the GIS unit

6.4.1 Organisational charts – big picture

Figure 6.2 gives the organisational chart of the Eskom group known as Eskom Holdings Limited, of which the South African government is a 100% shareholder. Eskom Holdings Limited reports to the Minister of Public Enterprises. Figure 6.3 indicates the location of ESI-GIS within the Eskom group.

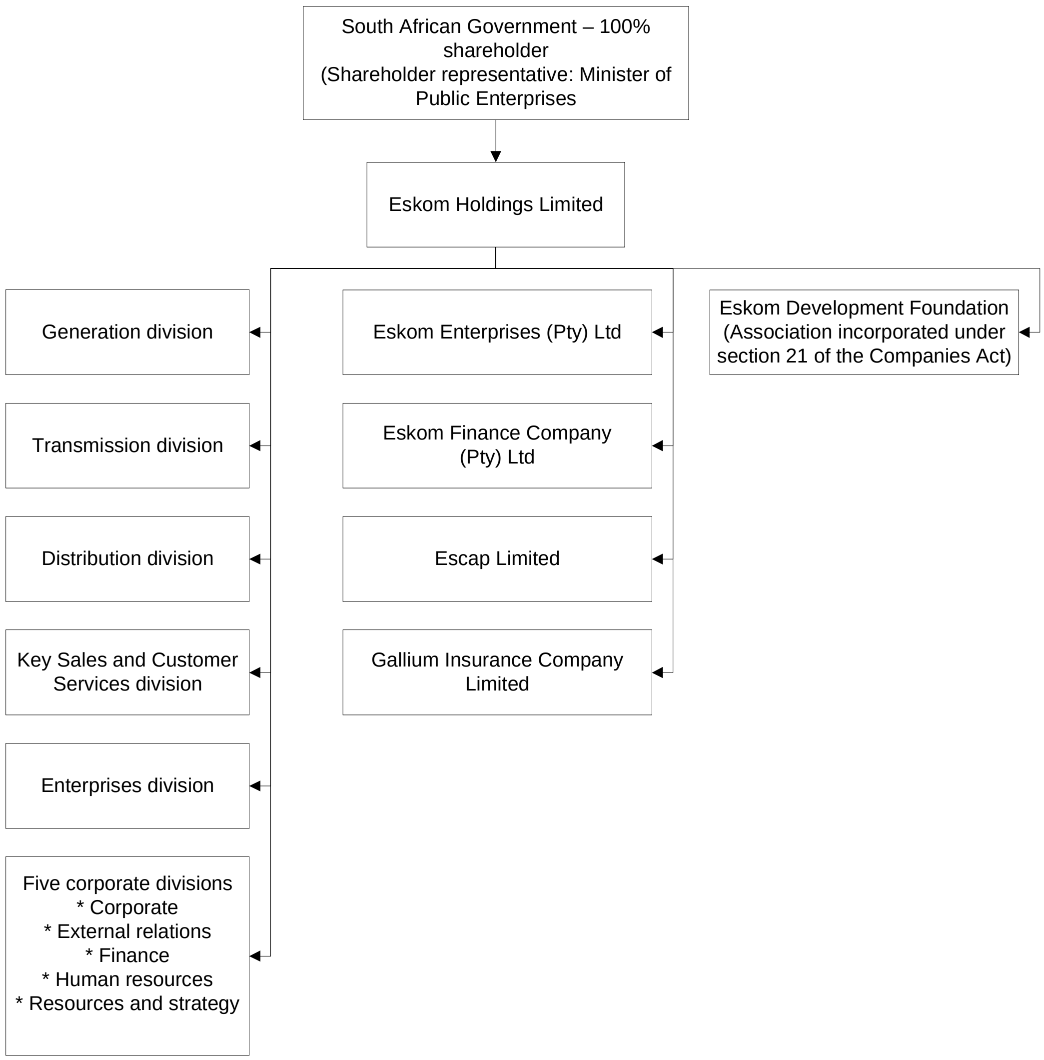

Figure 6.2: Organisational chart of Eskom Holdings Limited

(source: http//www.eskom.co.za/annreport/organisationstructure.htm downloaded on 8 January 2007)

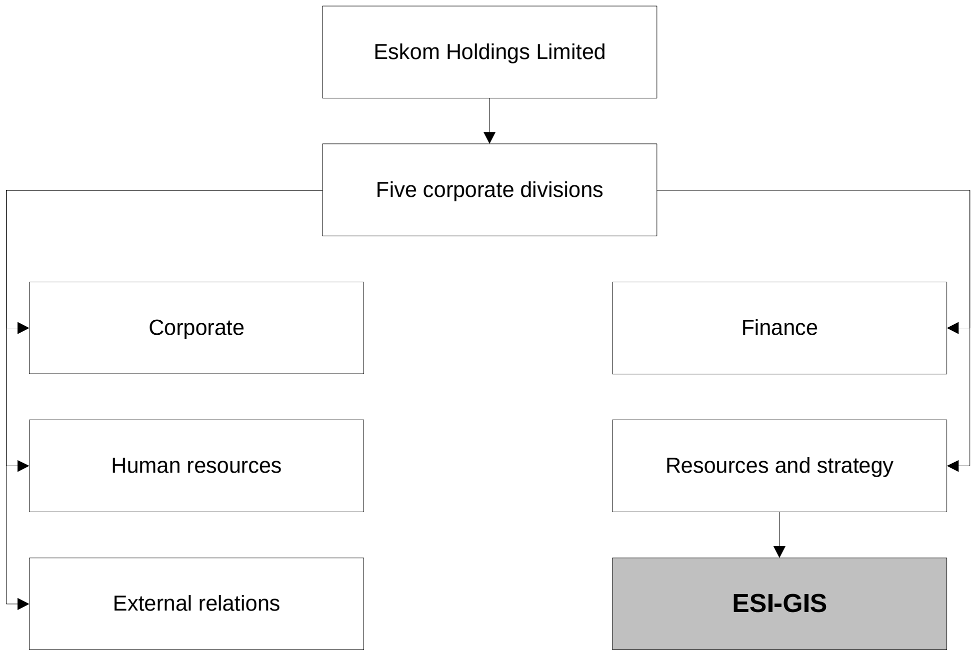

Figure 6.3: Location of ESI-GIS within the Resources and Strategy Division (from Van der Walt, 2007)

6.4.2 Organisational charts – the GIS unit itself

The chart in Figure 6.4 shows the organisation of ESI-GIS, which is currently divided into two groups: the Centre of Expertise and Data Management and Dissemination. The Centre of Expertise is responsible for spatial modelling such as site selection for new power stations or change detection in land-use patterns. Data Management and Dissemination is responsible for the collection, verification and dissemination of various spatial data and the GIS products created by ESI-GIS (De la Rey, 2006).

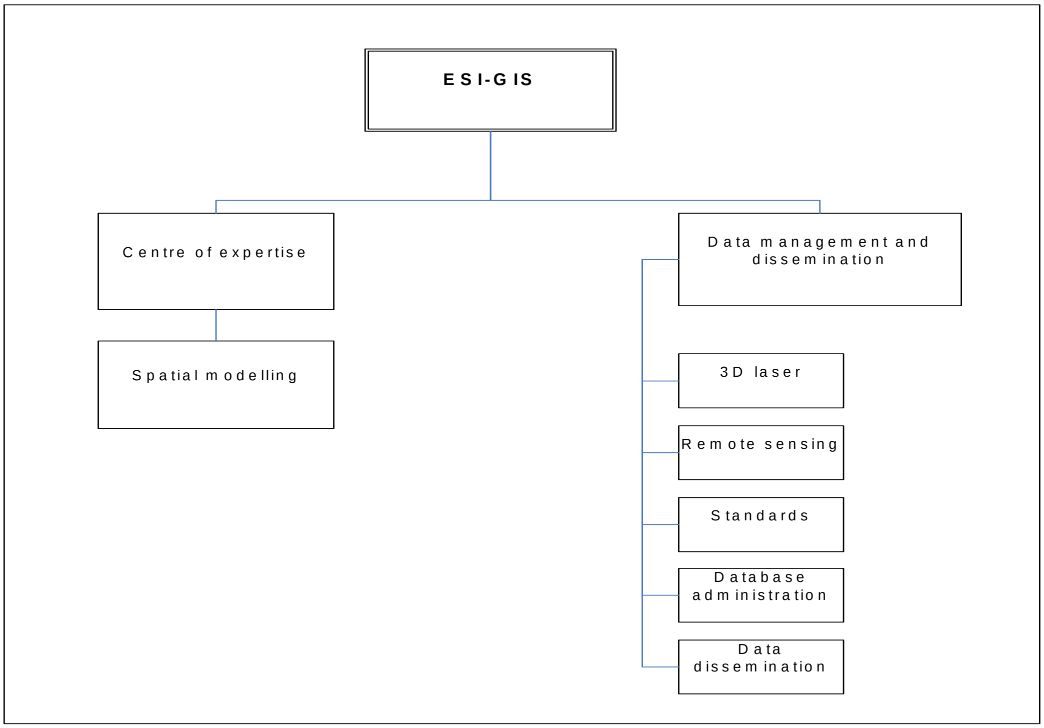

Figure 6.4: Organisational chart of ESI-GIS
(from De la Rey, 2006)

6.4.3 Location of the GIS unit

ESI-GIS is located at Komati House, Eskom Convention Centre, Midrand, Gauteng, South Africa (see Figure 6.1).

6.4.4 Functions within ESI-GIS

The manager of ESI-GIS is responsible for sales and business development. Once a project has been secured, it is handed over to the project manager.

The project manager's task is to plan, manage and execute fixed projects and ad hoc work. This person appoints a project leader for a specific project or ad hoc work. The appointed project leader then assembles the project team from the pool of skills available.

6.5 External and internal profile of the GIS Unit

6.5.1 External and internal customers

ESI-GIS has two broad categories of customers, namely those who are internal to the Eskom Group and external customers. The internal customers are:

- 726, which is the group responsible for rezoning the current seven Eskom regions into six regional electricity distribution regions (REDs)
- Eskom Distribution
- Eskom Telecoms
- Eskom Transmission
- ERID – Eskom Research and Innovation Department
- IARC – Industry Association Resource Centre
- INEP – Integrated National Electrification Programme
- RDD – Research and Development Department.

The external customers of ESI-GIS are:

- AfriGIS, a private GIS company which is a spatial data vendor and which also does consulting work involving spatial modelling
- Alex Fortescue, an independent spatial data broker
- Africon, an international consulting firm with strong GIS capabilities
- Department of Minerals and Energy (DME)
- Development Bank of Southern Africa (DBSA)
- Kirney, a private GIS company which is a spatial data vendor and which also does consulting work involving spatial modelling
- MapSmart, a private GIS company which is a spatial data vendor which also does consulting work involving spatial modelling
- Nedplan, a private GIS company which is a spatial data vendor which also does consulting work involving spatial modelling
- Statistics South Africa (StatsSA), a government institution which provides demographic and socio-economic data in South Africa.

ESI-GIS's customers can be grouped into the following broad categories:

- Parastatals (e.g. Eskom, CSIR)
- Public organisations (e.g. government, municipalities, etc.)
- Private organisations (e.g. consultants)
- *Ad hoc* projects.

The following customers use 80% or more of the GIS products created by ESI-GIS.

- DME
- Eskom Group.

Although as mentioned in Section 5.3, the DME established their own GIS, ESI-GIS still has to supply GIS products to the DME.

6.5.2 Internal and external suppliers

Internal suppliers of GIS products are those units within the Eskom Group that supply GIS products to ESI-GIS.

Suppliers of GIS products:

- Alex Fortescue
- AfriGIS
- Airborne Laser Services, which uses laser scanners to develop high-resolution digital elevation models
- ASTRATA, a private company that provides survey equipment, such as survey quality GPS solutions and 3D laser scanners
- Bentley South Africa – Bentley Systems (software provider)
- Demarcation Board – Governmental areas of interest such as municipalities, magisterial districts, etc.
- ESI-GIS – Creates vector maps of areas of interest (internal supplier)

- Geospace (spatial data supplier)
- GIMS – ESRI products
- SA Explorer – General data of South Africa, i.e. mining, major routes, towns, etc.
- Satellite Applications Centre (CSIR) – Change detection maps (1996 – 2001) and satellite imagery such as SPOT 5
- Six Eskom regions – Network data (132 kV to 1 kV), polygons of electrified villages and previously disadvantaged areas (internal supplier)
- Stats SA – Demographic data
- Surveyor General – Cadastral maps and information
- Surveys and Mapping: Mowbray – Topo-cadastral and 1:50 000 vector maps
- Africon
- Nedplan.

The above suppliers can be grouped into the following broad categories, namely:

- Suppliers of software, including software support and training
- Suppliers of data (spatial and non-spatial).

The following suppliers provide 80% or more of the GIS products supplied to ESI-GIS:

- Alex Fortescue
- AfriGIS
- Airborne Laser Services
- Eskom.

6.6 GIS products generated by ESI-GIS

As illustrated and concluded in Chapter 5, supply chain management can be used to manage the creation of GIS products. Examples of the various GIS products are discussed, and a high-level overview of the different supply chains involved using the GDS model approach is given in this section to explain why it is important to apply supply chain management in the creation of GIS products. In the context of this study, service is seen as a GIS product, since the outcome of the service is a spatial data set. The only non-spatial GIS products are the various standards created in-house by ESI-GIS.

The following GIS products are generated by ESI-GIS (ESI-GIS, 2006b):

- Spatial data management and dissemination
- Spatial data analysis and scenario modelling
- Production of hard-copy maps and customised data sets
- Data sourcing
- Developing standards for spatial data
- Consulting and advisory services
- Experienced and committed resources who understand the importance of meeting client expectations to achieve bottom line results and productivity
- Products/services that meet the customer's requirement in cost-effective manner which are implemented according to ISO 9001:2000 standards
- Data products created by ESI-GIS: namely aerial photography, change detection, fire burn scar mapping, Housing and Electrification Load Programme (HELP) data, 3D laser scanning and site selection.

6.6.1 Spatial data

This section gives a few examples of the GIS products created by ESI-GIS that are listed above.

6.6.1.1 Laser scanner

The 3D laser scanner was acquired by ESI-GIS in 2006 and will be primarily used to scan Eskom substations to develop as-built plans (Van der Walt, 2006a). Figure 6.5 shows a substation and Figure 6.6 shows the direct point cloud generated by the laser scanner for the same substation. Figure 6.7 shows another substation from which CAD drawings in three dimensions (Figure 6.8) and plan (Figure 6.9) were generated from the direct point cloud of the laser scanner data.

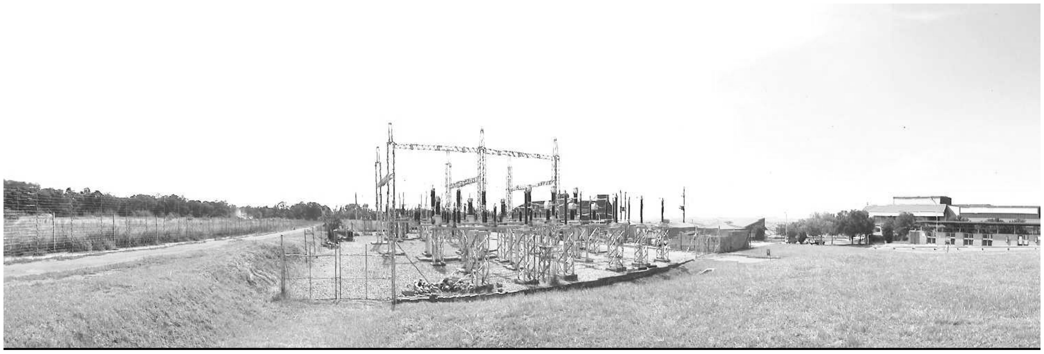

Figure 6.5: Actual site of the first substation scanned by a 3D laser scanner

(from van der Walt, 2006b)

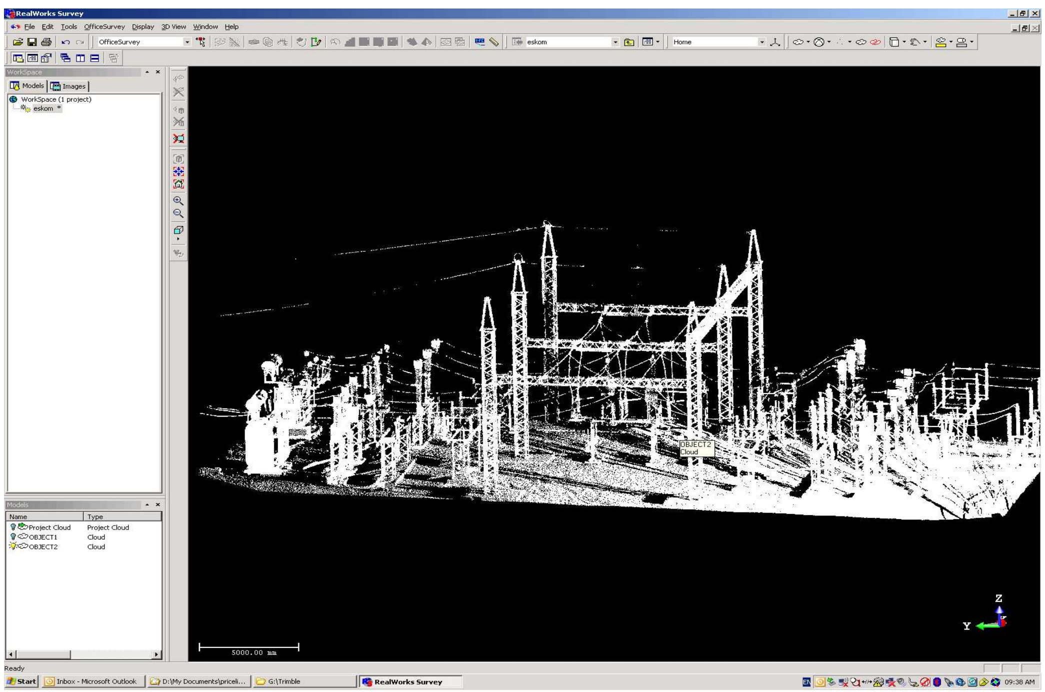

Figure 6.6: The same substation scanned by the 3D laser scanner showing the direct point cloud

(from van der Walt 2006b)

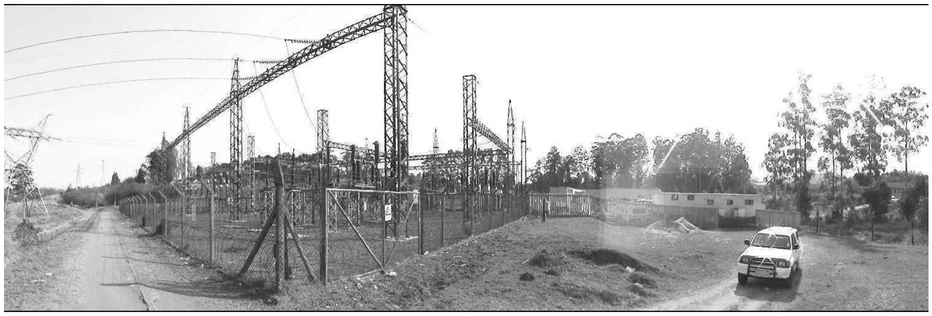

Figure 6.7: The second substation example

(from van der Walt, 2006b)

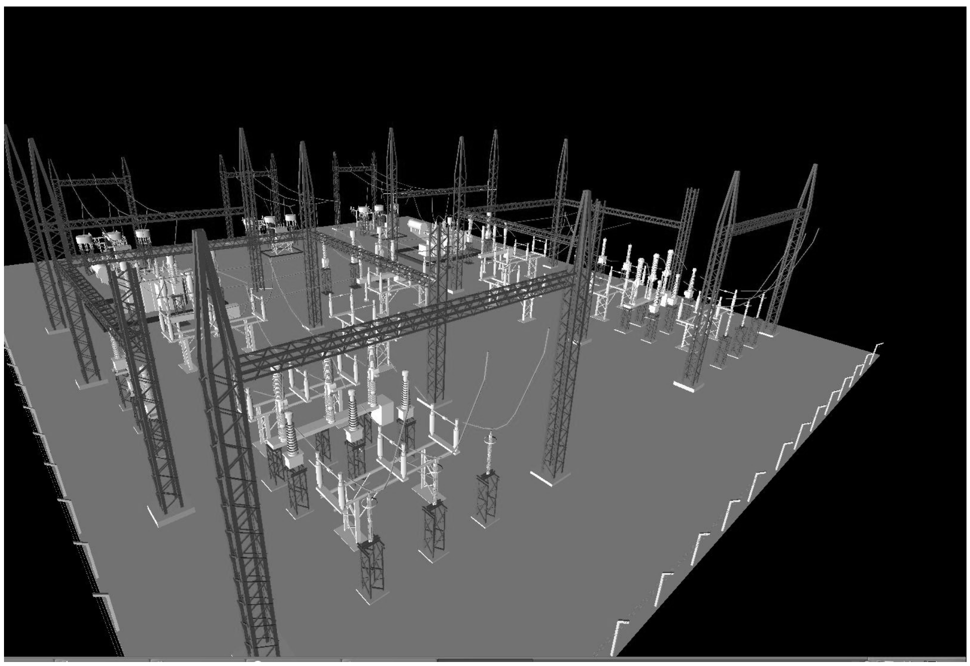

Figure 6.8: The 3D model of the substation in Figure 6.7 generated from the direct point cloud

(from van der Walt, 2006b)

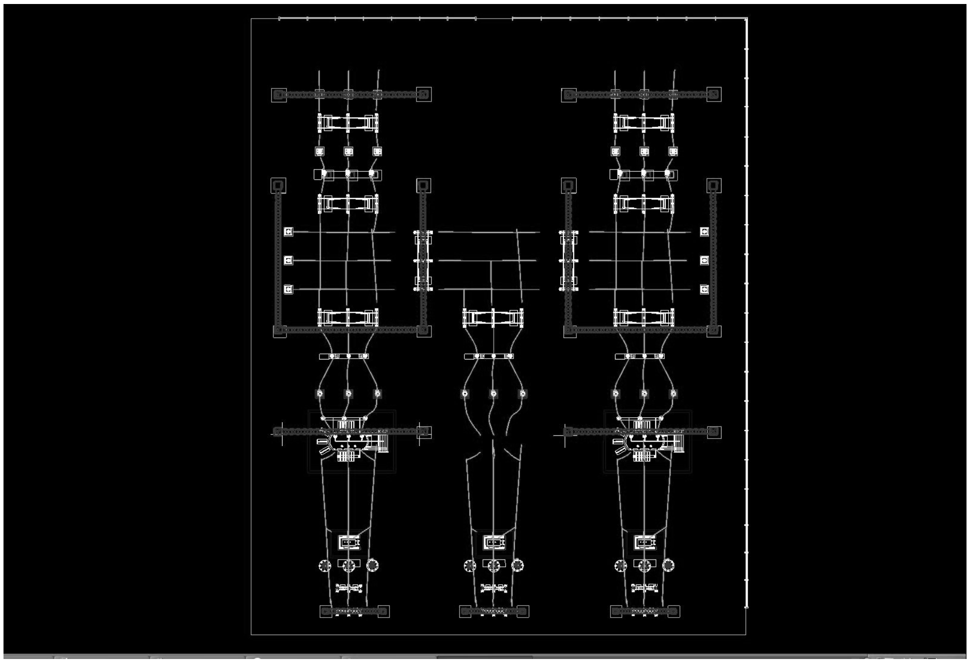

Figure 6.9: Plan view of the substation in Figure 6.7
(from van der Walt, 2006b)

The supply chain of the GIS product created by using a 3D laser scanner can be briefly described as follows, using the five management processes of GDS:

- PLAN – The supply chain is planned by establishing the need for such a GIS product. If the GIS product is needed, the available resources are balanced against the requirements of the supply chain. The requirement is to create the GIS product. The resources are staff, equipment (3D laser scanner), software, data storage, transport, etc.
- SOURCE – ESI-GIS does the scanning themselves. ESI-GIS staff go to the selected site(s) and scan the site such as the one shown in Figure 6.5. The data are then downloaded onto a laptop computer at the site and taken back to ESI-GIS.
- MAKE – The creation of various GIS products using the raw data collected (Figure 6.6). These products are 3D models of the scanned site (Figure 6.8) and a plan view derived from the 3D model (Figure 6.9).
- DELIVER – Involves the delivery of the created 3D model or plan to the customer such as Eskom Distribution.

- RETURN – Deals with faulty 3D models or plan views that were created by ESI-GIS. This may necessitate the return by ESI-GIS staff to the site to redo the scanning. A possible error could be wrong coordinate readings for the control points, the point directly below the scanner, which indicates the location of the scanner in latitude and longitude.

The management of the above production is known as supply chain management, the aim of which is to make the collection, creation and delivery of the data in the form of a GIS product as efficient and effective as possible. It also involves quality control during the sourcing and creation of the GIS product as well as final quality control before it is delivered to the customer. Customer relationship management and marketing are also integral parts of supply chain management.

6.6.2 Standards for automated mapping and facilities management (AM/FM)

ESI-GIS established a standards sub-section with their Data Management and Dissemination sections to ensure uniform standards for spatial data and GIS products that are captured, collected, maintained, customised and created by ESI-GIS. The spatial data standards developed by ESI-GIS are based on the national standards as published by Standards South Africa, which in turn are based on the ISO 19100 suite of standards as well as the standards associated with the survey industry in South Africa. Figure 6.10 gives an overview of the spatial data standards used by ESI-GIS.

Although standards are not a spatial product, supply chain management can be used to manage the creation of the various standards. The supply chain using SCOR is as follows:

- PLAN – Involves planning of the standard and assigning resources such as available staff and the various standards needed to create the in-house standards for Eskom regarding spatial data and the GIS products created by ESI-GIS.

- SOURCE – This is the sourcing of the applicable documents describing the standard, such as the ISO 19115 Geographic Information - Metadata standard or the SANS 1876:2005 Feature Instance Identification standard as well as other documents that may be needed to assist ESI-GIS to establish the in-house standards. Various standards are published by local and international institutions. The local supplier of standards is Standards South Africa (StanSA) and the international supplier is ISO. The various international standards pertaining to GIS are listed in Appendix A and the South African standards are discussed in Section 3.4.5.3.
- MAKE – Deals with the actual creation of the various standards. Figure 6.10 shows the process that was followed to create the SCSASACL7 Standard Specification for Importing Spatial Data into GIS by ESI-GIS.
- DELIVER – Concerns the delivery to and implementation of the developed standards at the different regional offices and other internal GIS product users of Eskom.
- RETURN – Deals with any problems relating to the distribution and implementation of the developed standards.

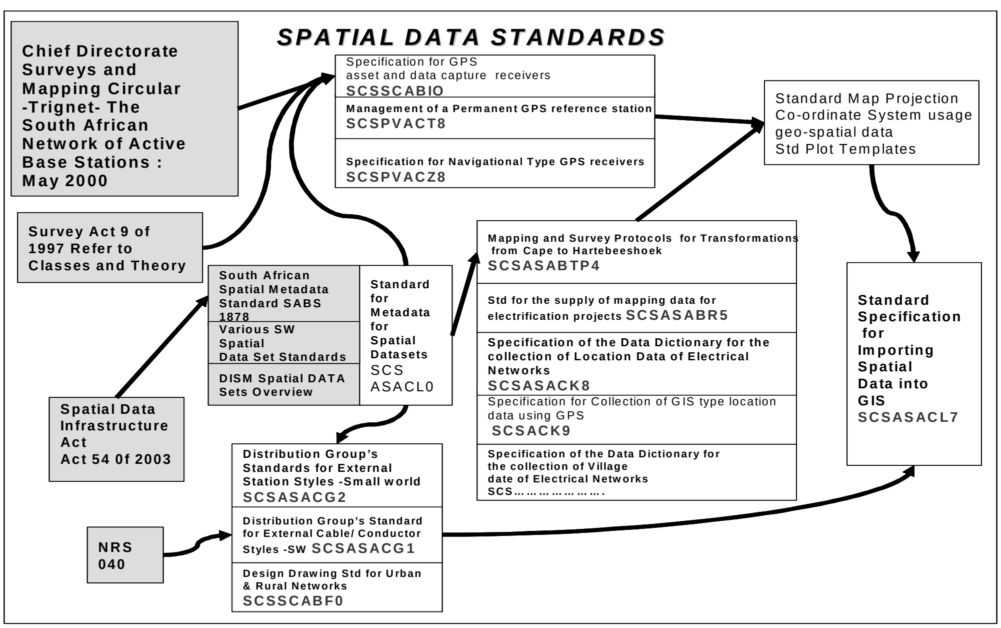

Figure 6.10: Various standards developed and used by ESI-GIS relating to spatial data and GIS products

(from ESI-GIS, 2006b)

6.6.3 Spatial modelling

As stated in Section 6.4.2, ESI-GIS consists of two sections, namely the Centre of Expertise and Data Management and Dissemination. In this section of the study a few examples of GIS products created by the Centre of Expertise's Spatial Modelling sub-section are discussed. The first example is the selection of a site for a new electricity generator.

6.6.3.1 Site selection

This is an example of determining a suitable site for a new coal-fired electricity generating plant for Eskom. The following criteria and assumptions regarding suitable site selection have been identified as follows (Makungo *et al.,* 2006):

- 3 600 MW plant
- Dry cooled with a water requirement of 7 million cubic metres (3.5 million m^3 for plant and 3.5 million m^3 for (FGD) flue gas desulphurisation)
- Within 50 km of coal reserves in excess of 480 Mt
- Within 200 km of limestone/dolomite sorbent sources
- Further than 10 km from urban residential areas
- Closer than 35 km from urban centres (skills base and load centres)
- Closer than 35 km from road and rail infrastructure
- Plant cannot be sited in the following areas:
    - Protected areas
    - Prime agricultural land
    - Biodiversity endangered areas
    - Potential areas for tourism investment initiatives
    - Dams and lakes
    - Areas with high levels of air pollution.

Figure 6.11 shows suitable sites based on the above criteria and assumptions for developing a new coal-fired electricity generating plant. Figure 6.12 shows a detailed map of the Bloemhof/Ventersburg site showing land cover and farm boundaries.

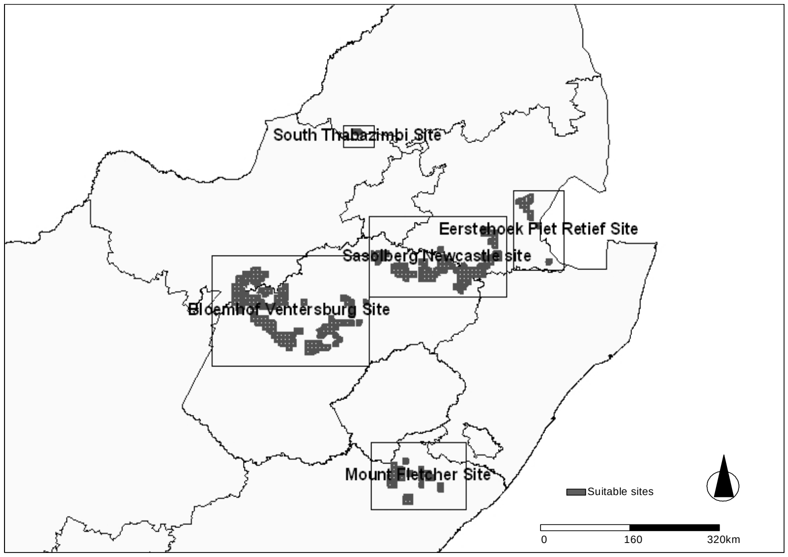

Figure 6.11: Suitable sites for a coal-fired electricity-generating plant

(from Makungo et al., 2006)

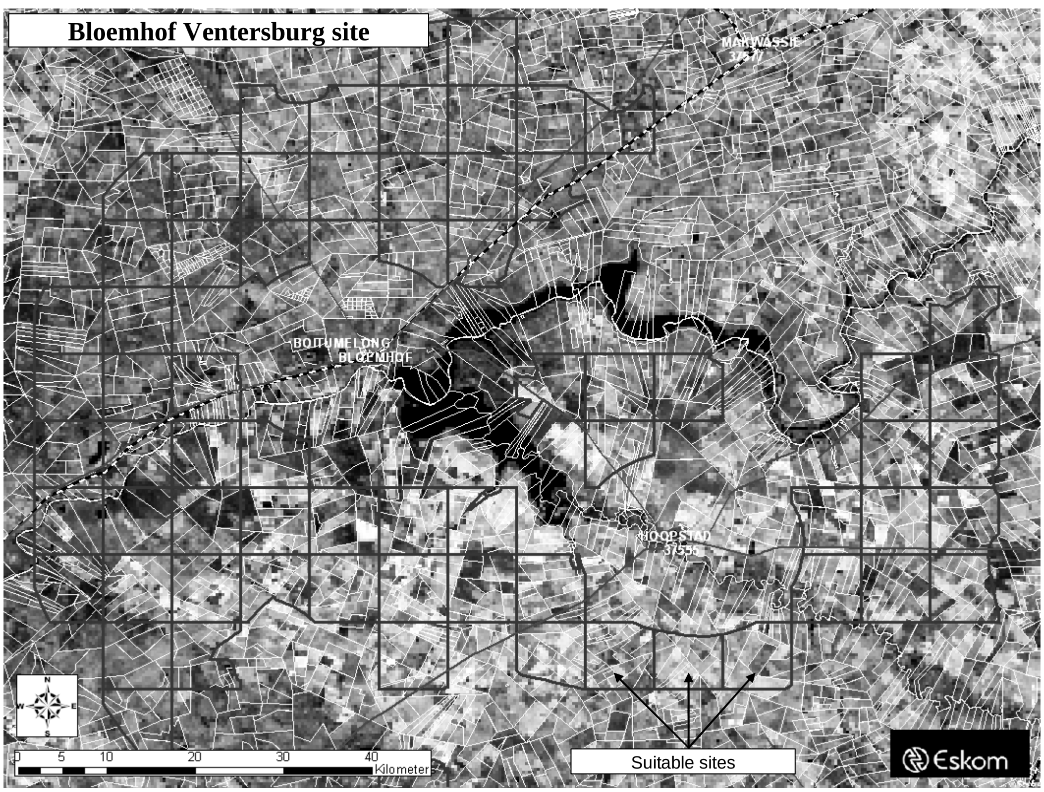

Figure 6.12: The Bloemhof/Ventersburg site

(from Makungo et al., 2006)

The supply chain necessary to determine a suitable site for a new coal-fired electricity generating plant, using the SCOR management process, can be described as follows:

- PLAN – Planning of the supply chain, which includes the planning of the sourcing of the different spatial, related non-spatial and other data from various suppliers, the planning of the GIS product creation (suitable site for a generator plant), which includes balancing the resources against the requirements to create the GIS product, and the planning of the delivery of the final GIS product to Eskom's Project Development Department. The last planning activity deals with the return of the GIS product to ESI-GIS and the return of sourced faulty spatial, related non-spatial and other data to the various suppliers.
- SOURCE – Is the actual sourcing of the different spatial, related non-spatial and other data needed to enable ESI-GIS to do a site selection. The type of spatial, related non-spatial and other data that have to be sourced from the various suppliers is determined from the above criteria and assumptions. Examples of spatial and related non-spatial data that have to be sourced are data on water bodies that show the locations of lakes and dams that form part of the no-go areas, but are also used to indicate the availability of suitable amounts of water required by the electricity generator plant; geological data showing the presence and size of coalfields and dolomite/limestone sorbent sources; land use and land cover maps showing urban areas, residential areas, agricultural activities, etc.; and road and rail data required to satisfy the criterion of "closer than 35 km from road and rail infrastructure". The sourcing activity includes the placement of the orders, the reception and verification of the sourced items, the loading of the sourced items on a removable hard disk (RHD) and payment of the suppliers.
- MAKE – Is concerned with the actual creation of the GIS product showing the best sites (see Figures 6.11 and 6.12). The processes involved are the scheduling of creation, the development of a cartographic model which

shows the spatial, related non-spatial and other data, and the different functions such as RECLASS, BUFFER, OVERLAY and JOIN. The cartographic model guides the physical creation of the GIS product. Once the GIS product has been created satisfactorily, it is then released for delivery to the customer.

- DELIVER – Concerns the scheduling of the delivery of the GIS product to the customer; the of delivery such as loading the results on a CD-ROM or DVD and sending it by courier or delivering it personally to the Eskom Project Development Department; and invoicing and receiving payment from the department.
- RETURN – How to deal with faulty spatial, non-spatial and other data received from suppliers or a faulty GIS product delivered to the customer (Eskom Project Development Department).

Supply chain management is used to ensure the efficient and effective operation of the supply chain to create the GIS products. It includes detecting problems within the supply chain, corrective actions required to solve the problems, quality control and the establishment and maintenance of supplier and customer relationships within the supply chain.

6.6.3.2 Change detection

Demographic data are necessary to plan the electrification of households. One of the methods to determine priority areas is to map demographic change and rank the size of change in square kilometres from large to small, giving priority to larger areas (De la Rey, 2006). Figure 6.13 shows a poster developed by ESI-GIS to explain the process of detecting demographic change using the 1996 Census enumerator data and superimposing it on a 2001 satellite image to detect changes in population.

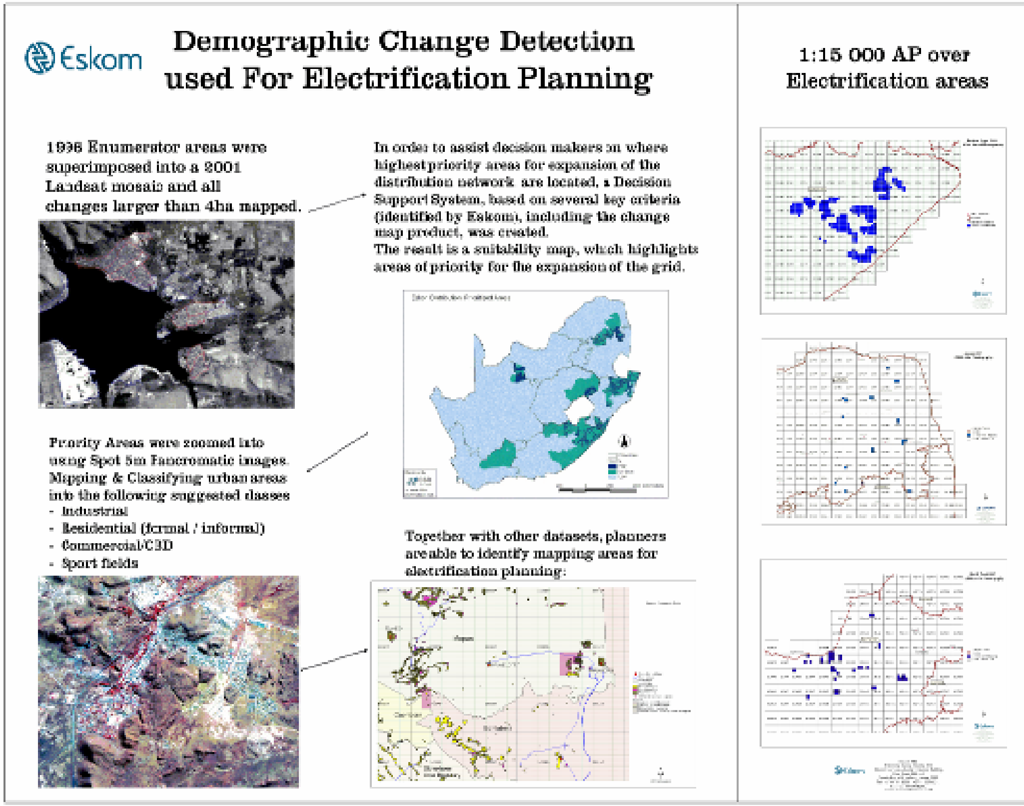

Figure 6.13: Poster illustrating demographic change detection

(from ESI-GIS, 2006c)

The supply chain and supply chain management aspects are similar to those discussed in Section 5.6.3.1.

6.7 Conclusions

This chapter gives an overview of ESI-GIS, the reason for its existence, the products that ESI-GIS creates and its strengths and weaknesses which impact on its day-to-day activities. Section 6.5 discusses ESI-GIS's suppliers and customers. Section 6.6 gives an overview of the main GIS products which ESI-GIS creates to support the electricity industry in South Africa.

ESI-GIS currently uses some elements of supply chain management such as quality control by setting standards; project planning to create the various GIS products; customer and supplier relationship management on an ad hoc basis; the sourcing of spatial, related non-spatial and other data; and delivery of the GIS product to the customer. These elements are, however, currently managed in isolation and not as an integrated supply chain (De la Rey, 2006). Section 6.6 also presents a high-level overview of supply chains and supply chain management for each example to illustrate the possible use of these to ensure the efficient and effective creation of a GIS product by ESI-GIS.

To test the validity of the high-level examples of supply chains and supply chain management, it is necessary to break these high-level descriptions down into more detailed levels to show the different process elements involved in modelling the supply chain and to locate problems within the supply chain and the management of the supply chain.

This chapter provided the GIS unit as required to partly answer objective E. To understand ESI-GIS's supply chain as alluded to above as to provide an input into managing it effectively and efficiently, a model is needed to analyse the supply chain. The application of the SCOR model to ESI-GIS's GIS product creation supply chain and to facilitate an answer to objective E is discussed in Chapter 7.

Chapter 7: The use of supply chains and application of supply chain management at ESI-GIS

7.1 Introduction

Chapter 5 discussed the use of supply chain management in a GIS environment using the SCOR model as an example to illustrate the supply chain and its elements. This enables a GIS unit to understand its supply chains and provide input so that it can apply supply chain management to improve its efficiency and effectiveness in the creation of GIS products.

This chapter aims to realise objective E: **Can supply chain management be used to successfully manage the production of GIS products by a selected GIS (ESI-GIS)?** In order to achieve this objective, this chapter first discusses the research design and methodology to collect the data and model and analyse the supply chain to provide a basis for the analysis. Two supply chain analysis sessions were held to collect data and model and analyse ESI-GIS's supply chain. The first analysis was done in March 2005 using the SCOR model version 5.0 as published by the Supply-Chain Council in 2001. One of the outcomes of this analysis was that the SCOR model had to be adjusted for the GIS environment, which resulted in the development of GDS which is discussed in this chapter. The second supply chain analysis using GDS was started in October 2006 and ended in May 2007 due to the availability of ESI-GIS staff, since ESI-GIS was working on a major project for a customer during the time of the analysis. The long time period needed was also due to the comprehensiveness of the GDS Level 3 analysis of the supply chain. The product range investigated in both field studies is ESI-GIS's spatial data GIS product range.

7.2 Research methodology

7.2.1 Research design

The research objective of this study as formulated in Section 1.5 is to determine whether the concept of supply chains and the use of supply chain management can assist GIS units to be more efficient and effective in the use of GIS when creating and delivering a GIS product. The research design used in this study to achieve this objective is based on evaluation research as discussed by Campbell and Stanley (1966) combined with the mixed methods research as proposed by Johnson and Onwuegbuzie (2004). Evaluation research according to Campbell and Stanley (1966) looks at the impact of policies introduced by government using the experimental or quasi-experimental approach. This study examines the impact of supply chains and supply chain management on a GIS unit. The result of the impact is that the GIS unit will be more effective and efficient in creating GIS products.

The experimental and quasi-experimental research design of Campbell and Stanley (1966) consists of control and experimental groups, where the participants should be selected randomly to effectively test the impact of a policy. In the context of this research, this means that several GIS units should be selected as the control group, and that for the duration of the study (which could last several years), they should not implement supply chains and supply chain management to improve their efficiency and effectiveness, whereas the experimental group should implement them to allow measurement of the impact of their use on improving the effectiveness and efficiency of the GIS units. It would be unrealistic and even unethical to expect this of participating GIS units, especially since they are in most instances competing GIS units that provide the same range of GIS products. This concern was raised by Rossi and Wright (1984) when trying to establish the relative effectiveness of private and public schools. To overcome this obstacle, it was decided to use a single GIS unit to establish whether the efficiency and effectiveness of a GIS unit could be improved through the use of supply chains and supply chain management and to publish the results, and then as a future research project solicit participants on a voluntary basis to establish the extent of the impact using the experimental research method or any other appropriate research method.

The mixed methods research allows the use of both quantitative and qualitative research methods to achieve the research aim (Johnson and Onwuegbuzie, 2004). With regard to this study, the quantitative aspect is the various metrics such as those from the original SCOR and GISDataSCOR (GDS) models used to assess the impact of the GIS unit using supply chains and supply chain management. The qualitative aspect of this research is the collection data during face-to-face interviews with the management and staff of ESI-GIS by the author. This included information on disconnects (problems) experienced by management and staff, steps involved in executing a process element and the existing business practices and rules. These were collected using workbooks for each of the five management processes in the GDS model. Financial data were obtained from ESI-GIS year-end financial statements.

The quantitative data from the financial statements and workbooks were captured in tables and spreadsheets to measure the performance of ESI-GIS's supply chain at the various SCOR and GDS model levels. The qualitative results were linked to the quantitative results in order to improve the supply chain of ESI-GIS through supply chain management.

The methodology that was used to collect the data, model and analyse ESI-GIS's supply chain was based on the method proposed by Bolstorff and Rosenbaum (2003). They based their methodology using the SCOR model on the following philosophy (Bolstorff and Rosenbaum, 2003: xvii):

> *"If you can* <u>define</u> *your supply chain – which isn't hard to do – then you can* <u>measure</u> *it. … Once you've measured it, you'll find the opportunities are so big that you won't need any more motivation. You'll want to* <u>drive continuous improvement</u> *in your supply chain."*

Based on the above, the SCOR model is used by Bolstorff and Rosenbaum (2003) to define the supply chain using the five management processes, PLAN, SOURCE, MAKE, DELIVER and RETURN and their related Level 2 process categories, process elements and enable processes as discussed in Chapters 2 and 5. Once the supply chain has been defined it is evaluated to establish its performance, and based on these results the required improvements are made and implemented. For a full discussion of the methodology proposed by Bolstorff and Rosenbaum, the reader is referred to their book *"Supply Chain Excellence"* published in 2003. An in-depth discussion of the methodology proposed by Bolstorff and Rosenbaum is outside the scope of this research. The SCOR model does give an indication that the analysis has to start at Level 1, which defines the scope and content of the model. On this level as well, the analysts should collect information about the competition, and the competition targets are determined. The next step in the analysis is the mapping of the supply chain at Level 2 using the different process categories to determine which of these are applicable to the firm or organisation investigated. At Level 3, detailed information about the supply chain is collected (Supply-Chain Council, 2001). The Bolstorff and Rosenbaum (2003) approach uses this information as a basis and expands on the modelling steps to provide a more detailed systematic approach than that given in the SCOR model itself, which is the reason for adopting the Bolstorff and Rosenbaum (2003) approach.

The methodology, which consists of several phases, is based on that proposed by Bolstorff and Rosenbaum (2003), and has been used to analyse ESI-GIS's supply chain. The phases are the following:

- The business context of a GIS unit.
- Performance and benchmarking using the SCORcard.
- Mapping the AS IS material flow.
- Doing the disconnect and opportunity analysis for each identified unique problem statement based on the disconnect analysis.
- Identifying areas of improvement by mapping and analysing the GIS unit's AS IS supply chain processes at SCOR Level 3 as well as mapping the TO BE processes at SCOR Level 3.
- Recommendations and implementations.

These phases are explored in more detail in the next few sections, starting with establishing the business context in which a GIS unit operates.

7.2.2 Business context

The business context, according to Bolstorff and Rosenbaum (2003), is used to gain an understanding of the business unit's or in particular the GIS unit's reason for its existence as well as the aims and goals of the organisation of which the GIS unit is part. The understanding of these aims, goals and strategies enables the unit to align its operations closely with the organisation's aims, goals and strategies. Table 7.1 gives the detailed steps based on the Bolstorff and Rosenbaum (2003) methodology.

Table 7.1: Business context – strategic profile

Item	**Description**
Business context – strategic profile	To understand the business context of the GIS unit.
Strategic background of the GIS unit	
Business description	Gives a high-level description of the GIS unit's business – normally the kind of information that is put in a brochure of a business.
Value proposition of the GIS unit	Description of the GIS unit from the customer's point of view. Common requirements according to Bolstorff and Rosenbaum (2003:27) are: price, product quality, technical innovation, customised packaging, delivery reliability, order lead time, strategic relationships and value-added services.
Critical success factors of the GIS unit	Not those factors that make the unit survive, but those that make the unit excel. 3 to 5 variables only.
Critical business issues	The issues that make the GIS unit unable to perform as it should, e.g. uncoordinated planning of projects, negative customer satisfaction, etc.
SWOT analysis	Analysis of Strengths, Weaknesses, Opportunities and Threats of the GIS unit.
Financial performance of the GIS unit	
Financial performance of the GIS unit	Financial statements of the GIS unit similar to those of firms given in their brochures (some GIS units may not run on a for-profit basis, but only on a service basis).
Internal profile of the GIS unit	
Organisational charts – big picture	If a GIS unit is part of an organisation, an organisational chart of the organisation shows where the GIS unit fits into the organisation.

Item	Description
Organisational charts – the GIS unit itself	The organisational chart of the GIS unit shows who is responsible for what and what the communication lines are.
Locations of the GIS unit	Provides the physical locations (town/suburb level) where the GIS unit has its operations and what these operations are.
Where within the GIS unit the planning, the management and the execution is done	The organisational chart is used to indicate where these activities are being done.
External profile of the GIS unit	
List of all suppliers and customers	Who are your data/service suppliers and who are your customers to whom you deliver GIS products?
List of suppliers who give most of the data/services	Here you use the 80/20 principle – 20% of your suppliers provide you with 80% of your data/service needs.
List of customers who use the most of your data/services	Here you use the 80/20 principle – 20% of your customers provide you with 80% of your data/service sales/provision.
Summarise your suppliers into broad categories – use input from Section 1.4.2	Here you summarise your suppliers into groups, e.g. suppliers of software and hardware, suppliers of spatial and related non-spatial data, etc.
Summarise your customers into broad categories	Here you summarise your customers into groups, e.g. government departments, parastatal organisations, consultants, etc. This section is important as these groups will be used to develop the supply chain matrix.
Supply chain matrix	
Develop supply chain definition matrix	In this section, the supply chain definition matrix is developed to give an overview of the GIS products and the customer/market channels of the GIS unit. The GIS products will be represented in the rows of the matrix and the customer/market channels will be given in the columns of the matrix. The customer/market channel uses the groups given in Section 1.4.5 plus the broad geography where they occur, e.g. SA government

Item	Description
	departments, SA parastatal organisations, SA consultants, SADC consultants, etc. See Table 7.2 for an example of a supply chain matrix. Once the matrix is developed and populated, the products and channels for the project will be selected. Using the information from Table 7.5, you have 5 supply chains from the customer/market channels perspective or 4 supply chains from the product point of view. If you mix the two and count the Xs then you have 8 supply chains. The supply chain(s) you want to analyse can be chosen from any of these perspectives.

Table 7.2: Supply chain definition matrix

(Based on Tables 3 –and 4 in Bolstorff and Rosenbaum, 2003:40)

SC definition matrix	**Geography of customers/market channel**				
Product	SA government departments	SA parastatal organisations	SA consultants	SADC consultants	Other
GIS product A			X		
GIS product B	X			X	
GIS product C	X		X		X
GIS product D		X	X		

Once the business context of the GIS unit has been established, the unit's performance needs to be determined. This allows the unit to evaluate its own performance and compare itself with its competitors.

7.2.3 Performance and benchmarking

Table 7.3 describes the various performance criteria that are used to compare the GIS unit against its competitors. The method used is known as the SCORcard and is described in Bolstorff and Rosenbaum (2003). The SCORcard was developed by the Supply-Chain Council in 2001 as referenced in Bolstorff and Rosenbaum (2003). This SCORcard is based on the information collected from the GIS unit and its competitors as given in Table 7.3. The SCORcard consists of the following column headings:

- Performance attribute or category – gives the overall category that will be measured; each attribute/category is broken down into a few metrics.
- Level 1 Performance metrics – these are criteria that are measured and compared against the competitors' performance.
- Actual – these are the values for each metric of the GIS unit.
- Parity – these are the median values (the value that splits the sample into two halves, 50%) of each metric derived from the sample of the GIS unit's competitors and the GIS unit itself.
- Advantage – these mid-point values lie between parity and superior as calculated from the sample and the GIS unit itself.
- Superior – these values lie in the 90th percentile (top 10%) of the sample and the GIS unit itself.
- Parity gap – these values are calculated by subtracting the GIS unit's actual values from the values in the Parity column.

If a GIS unit operates in a competitive environment, a SCORcard is then a useful instrument to see how effectively the GIS unit operates in comparison with similar GIS units, although it might be difficult to obtain the data necessary to do the comparisons. If it is very difficult to obtain data from the competitors or other non-competitive units, the SCORcard can still be used to measure the unit's own performance and identify costs, which can be reduced by streamlining the supply chain and improve the efficiency of the GIS unit. Table 7.3 also provides a description of the performance metrics and how to calculate the different values. The SCORcard is based on the SCOR model Level 1 performance metrics.

GISDataSCOR (GDS) uses the same performance metrics as the original SCOR model.

Table 7.3: SCOR metrics template for GIS units

(Based on Bolstorff and Rosenbaum, 2003:51 - 53)

	Performance Attribute / Category	**Level 1 Performance Metric**	**Description**	**Formula**
Customer facing	Supply Chain Responsiveness	Delivery Performance	Measures the percentage of orders delivered "on time and in full" to customer on request date and/or on customer commit date	(Number of customer orders delivered on time and in full) / (Total number of customer orders) expressed as % (rounded to the nearest %)
		Perfect Order Fulfilment	Measures the percentage of orders delivered "on time and in full" to customers on request date and flawless match of purchase order, invoice and receipt.	(Number of perfect (no comebacks) orders delivered on time and in full)) / (Total number of customer orders) expressed as % (rounded to the nearest %)
	Supply Chain Response Time	Order Fulfilment Lead Time	Measures the number of days from order receipt to delivery of GIS product to the customer's desk.	| (Actual delivery date) – (Order entry date)| for each customer order
	Supply Chain Flexibility	Supply Chain Response	Measures the ability of the supply chain in number of days to handle a significant increase or decrease of a specific GIS product without cost penalty	Source lead time for constraint item {data} (days) + manufacturing time for the GIS product (days) + order fulfilment lead time.

	Performance Attribute / Category	Level 1 Performance Metric	Description	Formula
Internal facing	Supply Chain Costs	Costs of Goods (Costs of goods sold – COGS)	Measures the direct costs of purchasing material (data and end-product material such as plotter ink, plotting paper and/or DVDs or CDs) and labour costs to produce a GIS product	Costs of data and materials + direct manufacturing labour costs to create the GIS product + indirect labour costs (i.e. contribution). [% = COGS / Revenue * 100] (Rounded to the nearest %)
		Total Supply Chain Management Costs	Measures the direct and indirect costs to plan, source and deliver a GIS product	Customer service costs + Data warehouse server(s) and related IT costs + Purchasing and acquisition costs + Planning costs.
		Sales, General and Administration Costs (SG&A Costs)	Measures the indirect costs of sales, administration and support services (such as IT support) to support the creation of a GIS product.	Costs for sales and marketing + costs for administration + costs for support services + consumables (includes electricity, water and phone bills) + cost of facility (rental or rates and taxes). [% = SG&A / Revenue * 100] (Rounded to the nearest %)
		Returns Processing Costs	Measures the costs involved in replacing defective GIS products, i.e. faulty data, missing metadata, etc.	Man-hour costs + costs of materials such DVDs and/or CDs and/or plotter ink and paper

	Performance Attribute / Category	Level 1 Performance Metric	Description	Formula
	Supply Chain Asset Management Efficiency	Cash-to-Cash Cycle Time	Measures the number of days that cash is tied up as working capital	[Inventory (data) in Rand / (COGS / 365)] + [Sales (Receivables) in Rand / (Revenue / 365)] – [Payables (i.e. data that still have to be paid for) in Rand / (Material (data) costs / 365)].
Internal facing	Supply Chain Asset Management Efficiency	Inventory Days of Supply	Measures the number of days that cash is tied up as inventory	Inventory (data) in Rand / (COGS / 365) Data and non-working data inventory
		Asset turns	Asset turns is calculated by dividing revenue (Rand) by total net assets which consists of working capital and fixed assets	Revenue in Rand / (Working Capital + Fixed Assets).
Share or Stakeholder facing	Profitability	Gross Margin	Gross margin is calculated by subtracting COGS from revenue expressed as %	(Revenue in Rand – COGS in Rand) / Revenue in Rand. [% = Gross Margin / Revenue * 100] (Rounded to the nearest %)
		Operating Income (Margin)	Calculated by subtracting both COGS and SG&A from revenue expressed as %	(Revenue in Rand – COGS in Rand – SG&A in Rand) / Revenue in Rand. [% = Margin / Revenue * 100] (Rounded to the nearest %)

	Performance Attribute / Category	Level 1 Performance Metric	Description	Formula
		Net Income (Net Operating Income)	Calculated by subtracting COGS, SG&A and Tax from revenue expressed as a %	(Revenue in Rand – COGS in Rand – SG&A in Rand – Taxes in Rand) / Revenue in Rand. [% = Net Income / Revenue * 100] (Rounded to the nearest %)
	Effectiveness of Return	Return on Assets	Calculated by dividing Net Income by Total Net Assets	% = Net Income in Rand / Total Net Assets in Rand * 100 or % = Operating Income (Margin) / Total Assets * 100 (Rounded to the nearest first decimal %)

The easiest way of collecting and calculating the information is to use a spreadsheet where the column headings are the abovementioned variables and the row headings are the GIS unit and its competitors for which the information is collected, starting with the GIS unit first.

If it is possible to collect the data from the GIS unit's competitors, the following need to be calculated for each of the Performance Metrics listed in Table 7.3 (Bolstorff and Rosenbaum, 2003:63):

- "*Industry Parity*
- *Industry Advantage*
- *Industry Superior*" (90^{th} percentile).

These values are used to establish how well the GIS unit compares with its competitors. Table 7.4 gives methods of how to calculate the above variables.

Table 7.4: Method of calculating the comparison variables

(Bollstorf and Rosenbaum, 2003: 63).

Variable	**Method**
Industry Parity	Calculate the median (use a spreadsheet or a statistical package to calculate the median)
Industry Advantage	The mid-point between Parity and Superior [(Parity + Superior) / 2 {rounded to the first integer (no decimals)}]
Industry Superior - 90^{th}	Calculate the 90^{th} percentile (use a spreadsheet or a statistical package to calculate the 90^{th} percentile)

Table 7.5 gives the SCORcard (Bolstorff and Rosenbaum, 2003: 80) based on the results given in Tables 7.3 and 7.4. These SCORcards are then used to determine the opportunities to improve the GIS unit's competitiveness. These opportunities are based on the decisions as to whether a performance metric should be on parity, advantage or superior in comparison with the competition.

Table 7.5: The SCORcard for a GIS unit's GIS product

	Performance Attribute / Category	**Level 1 Performance Metric**	**Actual**	**Parity (P)**	**Advantage (A)**	**Superior (S)**	**Parity Gap (Actual – Parity)**	**Requirements Gap (Actual – P or A or S)**	**Opportunities**
Customer facing	Supply Chain Delivery Reliability	Delivery Performance							
		Perfect Order Fulfilment							
	Supply Chain Responsiveness	Order Fulfilment Lead Time							
	Supply Chain Flexibility	Supply Chain Response Time							
Internal	Supply Chain Costs	Costs of Goods (Costs of goods sold – COGS)							

	Performance Attribute / Category	Level 1 Performance Metric	Actual	Parity (P)	Advantage (A)	Superior (S)	Parity Gap (Actual – Parity)	Requirements Gap (Actual – P or A or S)	Opportunities
		Total Supply Chain Management Costs							
		Sales, General and Administration Costs (SG&A Costs)							
		Returns Processing Costs							
	Supply Chain Asset Management Efficiency	Cash-to-Cash Cycle Time							
		Inventory Days of Supply							
		Asset turns							
Shareholder facing	Profitability	Gross Margin							
		Operating Income (Margin)							
		Net Income (Net Operating Income)							
	Effectiveness of Return	Return on Assets							

7.2.4 AS IS material flow processes

Once the performance data have been collected and analysed at GDS Level 1, the next step is to start to unpack the supply chain to gain an understanding of the flow of spatial, related non-spatial and other data as well as GIS products to and from the GIS unit. For the purpose of this chapter the word **data** encompasses all spatial, related non-spatial and other data that are used by a GIS unit. Table 7.6 gives the AS IS material flow process. The AS IS material flow is shown on a geographic map where the locations of suppliers, data warehouses, GIS unit(s) and customers are. In the context of the GIS unit, the locations of offices that provide the raw data and where the GIS unit is located are mapped. Once these locations are mapped the flow of data between them is mapped. Once the flows are mapped, the SCOR Level 2 process of PLAN, SOURCE, MAKE, DELIVER and RETURN are mapped. SCOR is discussed in detail in Chapter 2. The AS IS material flow is based on the selected product as given in Table 7.2. If more than one product is selected, then the AS IS material flow process has to be mapped for each product.

Table 7.6: AS IS material flow processes

Process	**Method**
Geographic map showing locations of supplier(s), data warehouse(s) and manufacturing site(s) (GIS unit(s))	Use a paper map of a country or the world and map the locations using a pen or pencil. Indicate the location using different symbols for supplier, data warehouse or GIS unit (see Figure 7.1) (It can also be done electronically using a GIS).
Map the material flow between locations, and also indicate the method of transportation, i.e. ftp, CD, DVD, etc.	On the same paper map, draw lines of flow between the entities. Also annotate the method of transportation at each line (see Figure 7.1).
At each site map the SCOR Level 2 processes	At each site map the SCOR Level 2 processes. Figure 7.1 shows an example of how to do it. At this point the different process types in SCOR Level 2 must be identified, namely: Make-to-Stock, Make-to-Order, Engineer-to-Order or Maintain-to-Stock.
Convert the paper results into an electronic format.	Convert all the above into an electronic format, either using a GIS orany desktop publishing software, such as MS PowerPoint or MS Visio.

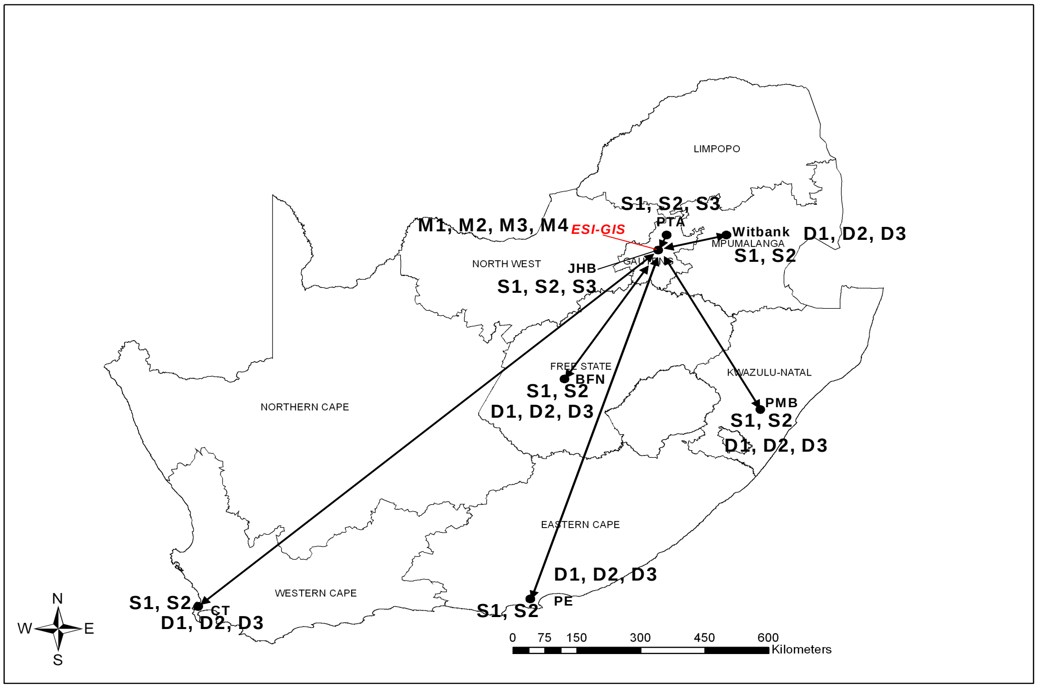

Figure 7.1: Mapping material flow

From the geographic map the supply chain is mapped using SCOR Level 2 as shown in Figure 7.2.

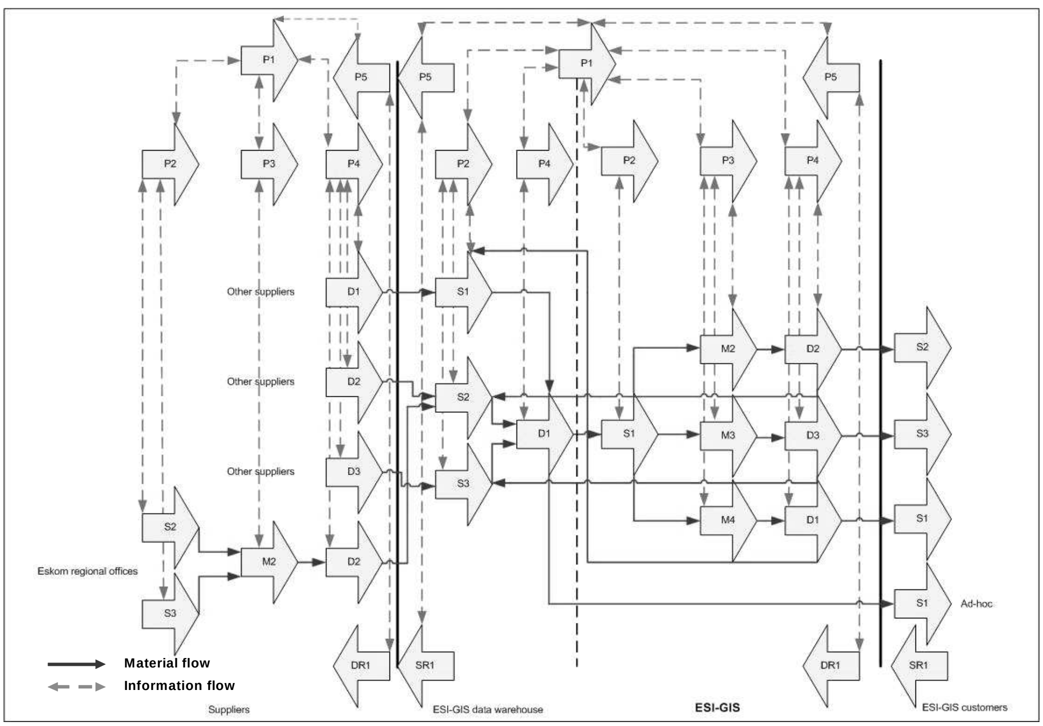

Figure 7.2: SCOR Level 2 process mapping

Once the material flow has been mapped, it is necessary to measure the material flow performance. Table 7.7 gives the metrics that will be measured based on Bolstorff and Rosenbaum (2003).

7.2.5 Disconnect and opportunity analysis

This section uses the information from the previous section to identify problems (disconnects) within the supply chain. According to Bolstorff and Rosenbaum (2003), 15 issues can solve a 1 000 problems, which can result in a 3% increase in profit once those issues have been solved. For this section a team must be assembled which is directly involved with the manufacturing of the GIS product. Table 7.8 gives the process of conducting the disconnect analysis, which is based on Bolstorff and Rosenbaum (2003).

Table 7.7: Material flow performance metrics

Location	Revenue	Data warehouse expense (server costs)	Transportation costs				Inventory			On Time		Lead Time (Days)			Returns[8]	
			Type	Inbound	Inter GIS unit[1]	Outbound		Raw data	GIS product	Inbound receipts[4]	Outbound shipments[5]		Inbound orders[6]	Outbound orders[7]	Type	Cost (Rand)
			Internet				Inv (Rand)					Median days			Labour	
			DVD/CD[2]				COGS (Rand)									
			Paper[2]				Days[3]					Maximum days			Outbound transport[9]	
			Drive space cost													

[1]Using share drives on the network that have to be paid for.

[2]Courier costs plus packaging.

[3]The number of days that data are kept in a data warehouse before it is backed up onto DVD/CD/tape and removed from the data warehouse. Some data are essential and will stay in the warehouse for a long time until it is upgraded. Use the median number of days that the data are kept on the data server.

[4]Percentage received on time = Number of orders placed received on time / Total number of orders placed.

[5]Percentage orders delivered on time = Number of orders delivered on time / Total number of order received.

[6]Median number of days it takes to get all the data needed from all the suppliers as well as the most number of days from any one supplier.

[7]Median number of days that are used to source, make and deliver a GIS product for repeat GIS products for various clients as well as the maximum number days to deliver the same product. If it is a once-off engineered-to-order product, use the maximum number of days column to enter the order lead time.

[8]Return in this context is the costs involved to correct a faulty GIS product.

[9]The costs involved getting the fixed GIS product back to the client (i.e. DVD/CD cost, courier or Internet costs).

Table 7.8: Disconnect analysis process

Step	**Procedure**
Identify team members	Team members consist of those who are involved in acquiring the data for the GIS product, the making of the GIS product and delivering the GIS product. There is also the project leader.
Identify location	A convenient location where a disconnect analysis can be held. Use the walls for the five SCOR elements. Have paper, whiteboard markers and Post-Its handy to do the disconnect analysis.
Identify a day for the disconnect analysis	Identify a day for the disconnect analysis and book the venue.
Short introduction to SCOR	Familiarise the team members with the five SCOR elements, namely PLAN, SOURCE, MAKE, DELIVER and RETURN. This is necessary because the issues can occur in each of the five elements.
Identify disconnects in each element	In this part of the exercise people write down disconnects in each element. Disconnects should be stated clearly, with an example and the frequency of occurrence where applicable. Paste the disconnect on the wall under the relevant SCOR element.
Group disconnects	Using the information, the disconnects are grouped together into problem groups for each SCOR element. For each problem group, there is a sentence describing the problem, an example and the metrics involved as given in the material flow performance table.

Document the disconnects	For each SCOR element, the problem group plus each disconnect that forms part of the group are documented. Table 7.9 gives an example of how to document the different disconnects.
Group the groups into unique problem groups	Using the information from Table 7.9, the groups can now be grouped into unique problem groups. The reason is that certain problem groups can occur in several SCOR elements and are repetitions of the problem. Keep track of the numbers of each group and disconnects as originally given in Table 7.9. Table 7.10 shows the unique problem grouping. This information will be used for the fishbone analysis as described in Section 5.

Table 7.9: Documenting the disconnects

(based on Bolstorff and Rosenbaum, 2003: 121)

SCOR element	**ID**
PLAN	1
Disconnect group statement 1	1.1
Individual disconnect or cause description	1.1.1
Individual disconnect or cause description	1.1.2
Individual disconnect or cause description	1.1.3
Disconnect group statement 2	1.2
Individual disconnect or cause description	1.2.1
Individual disconnect or cause description	1.2.2
Etc.	1.x
SOURCE	2
Disconnect group statement 1	2.1
Individual disconnect or cause description	2.1.1
Individual disconnect or cause description	2.1.2
Etc.	2.x
MAKE	3
DELIVER	4
RETURN	5

Table 7.10: Unique problem statements

Problem statement	New ID	Old IDs
Problem statement based on disconnect or cause description(s)	1	1.1; 1.2; 3.1; etc
Problem statement based on disconnect or cause description(s)	2	1.4; 2.1; 5.3; etc.
Etc.	x	

The above information (Tables 7.9 and 7.10) is used to create a fishbone analysis for each problem statement. Figure 7.3 gives an example of a fishbone diagram (Bolstorff and Rosenbaum, 2003). A description of the fishbone (cause-and-effect) diagram is given in Section 5.5.4.

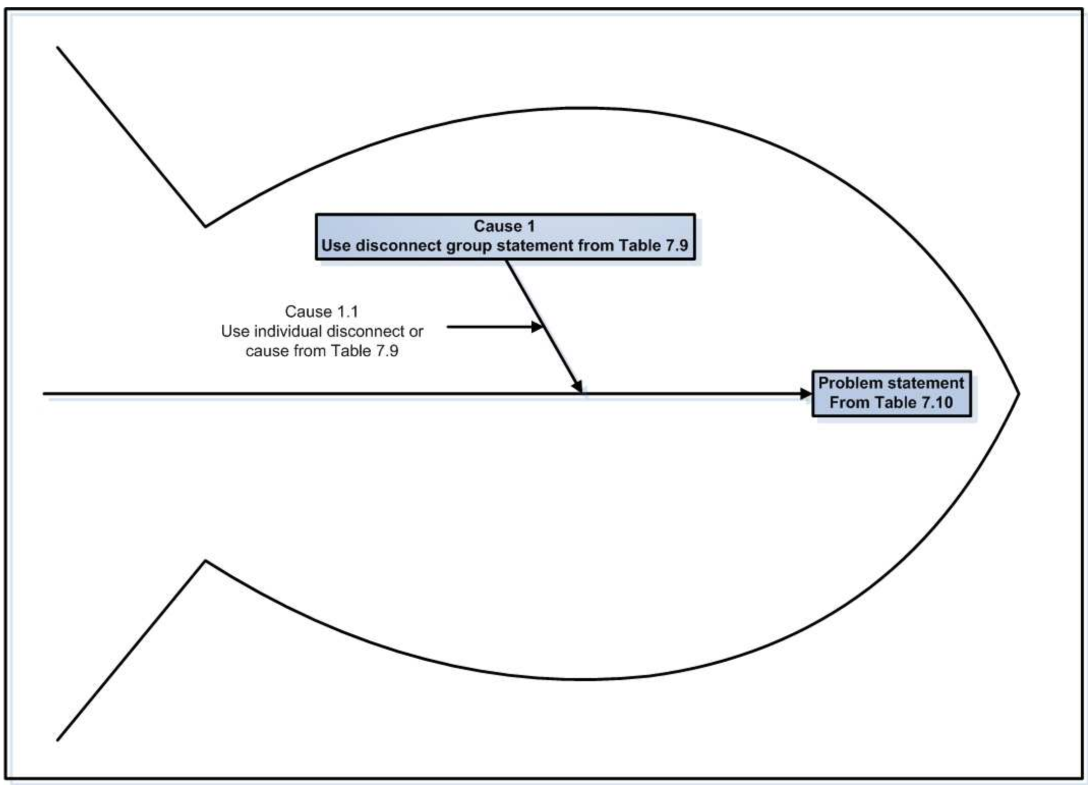

Figure 7.3: Fishbone analysis

(from Figs. 9 – 1 in Bolstorff and Rosenbaum, 2003: 123).

Once the problem statements and the cause-and-effect diagrams have been drawn up, the next step is to convert them into opportunities. An opportunity spreadsheet (base case and test scenario) using the information from the SCORcard is created for each problem statement. Using the problem statement "Lack of skills to perform high-end GIS operations" as an example, the GIS unit assumes that if the staff went on an advanced GIS training course to acquire the necessary skills, the productivity would improve, resulting in lower labour costs for the same amount of work. The GIS unit uses the opportunity spreadsheet to model several what-if scenarios, such as what would be the impact on the GIS unit's finances if labour costs dropped by three or five per cent due to improved skills? Table 7.11 shows the content of the opportunity spreadsheet as well as how to calculate the various variables.

Table 7.11: Opportunity spreadsheet

(based on Bolstorff and Rosenbaum, 2003: 130-1)

Type	**Value**	**Per piece/order**	**Calculation**
Transaction Summary			
Revenue	Rand	NA	NA
Orders	Total number of orders for GIS product/range type	Rand per order	(Revenue/ Orders)
Total Items on Orders	Total number of data layers per order (i.e. one order has 12 data layers, the second order has 4 data layers, thus the total items = 12 + 4 = 16)	Rand per item	[(Total number of orders)/(Total Items on order)]*(Rand per order)
Purchase Orders	Total number of purchase (data) orders	Rand per purchase order	(COGS (data))/(Total number of purchase orders)
Total Items Purchased	Total number of data layers purchased (see Total Items on Order for explanation)	Rand per purchase item	[(Total number of purchase orders)/(Total number of items purchased)]*(Rand per purchase order)
Service Level			
Perfect Supplier Fulfilment Rate	Number of orders for which the supplier	Percent	[(Number of correct orders)/(Total number

Type	Value		Per piece/order		Calculation
	provided the correct data expressed in percent				of orders)]*100
Perfect Order Fulfilment Rate	Number of correct orders given to the client expressed in percent		Percent		[(Number of correct orders)/(Total number of orders)]*100 or get it from Table 7.5 (SCORcard)
Order Fulfilment Lead Time	Number of days taken from order to delivery		Days		Get data from Table 7.5 (SCORcard)
Total Item Source Lead Time	Average days to source a data item (from order date to delivery date)	Total number of items (data) sourced = 100%	Days	Percent (100%)	Total number of items (data layers) purchased = 100% -- Total number of items = S1 items + S2 items + S3 items
S1 (Source stocked items)	Acceptable number of days	Total number of S1 items	Days	Percent	[(Total number of S1 items)/(Total number of items (data layers) purchased)]*100
S2 (Source Make-to-Order items)	Acceptable number of days	Total number of S2 items	Days	Percent	[(Total number of S2 items)/(Total number of items (data layers) purchased)]*100
S3 (Source Engineer-to-Order items)	Acceptable number of days	Total number of S3 items	Days	Percent	[(Total number of S3 items)/(Total number of items (data layers) purchased)]*100

Type	Value		Per piece/order	Calculation
Supply Chain Costs				
Production and Merchandise Costs (COGS)				
COGS: Data and Material Costs	Percent of Revenue	Cost of data and material in Rand (as part of the formula in Table 7.3 to calculate COGS)	Rand per purchase item (get it from Total Items Purchased row)	Percent of Revenue = [(Costs of data and material in Rand from the formula used in Table 7.3)/Revenue]*100
COGS: Labour costs (direct)	Percent of Revenue	Cost of labour (direct) in Rand (as part of the formula in Table 7.3 to calculate COGS)	Direct labour cost (Rand) per order item	Percent of Revenue = [(Costs of labour (direct) in Rand from the formula used in Table 7.3)/Revenue]*100 Direct labour cost (Rand) per order item = Rand per order item*[Percent of Revenue/100]
COGS: Labour costs (indirect)	Percent of Revenue	Cost of labour (indirect) in Rand (as part of the formula in Table 7.3 to calculate COGS)	Indirect labour cost (Rand) per order item	Percent of Revenue = [(Costs of labour (indirect) in Rand from the formula used in Table 7.3)/Revenue]*100 Indirect labour cost (Rand) per order item = (Rand per order item)*(Percent of Revenue/100)

Type	Value		Per piece/order	Calculation
Total Supply Chain Management Costs				
Customer Service Costs	Percent of Revenue	Customer service cost in Rand (as part of the formula in Table 7.3 to calculate Total Supply Chain Costs)	Customer service cost (Rand) per order item	Percent of Revenue = [(Customer service costs in Rand from the formula used in Table 7.3)/Revenue]*100 Customer service cost (Rand) per order item = (Rand per order item)*(Percent of Revenue/100)
Data warehouse (DW) and IT costs (orders) – Determine the percentage of DW and IT that is used to make the GIS product and determine the cost	Percent of Revenue	DW and IT costs in Rand [(Total cost)*0.X] Total costs from Table 7.3	DW and IT cost per order item	Percent of Revenue = [(DW and IT costs in Rand from the formula used in Table 2)/Revenue]*100 DW and IT cost (Rand) per order item = (Rand per order item)*(Percent of Revenue/100)
Data warehouse (DW) and IT costs (purchases) – Determine the percentage of DW and IT that is used for sourced data	Percent of Revenue	DW and IT costs in Rand [(Total cost)*0.Y] Total costs from Table 7.3	DW and IT cost per purchase item	Percent of Revenue = [(DW and IT costs in Rand from the formula used in Table 7.3)/Revenue]*100 DW and IT cost (Rand) per purchase item = (Rand per purchase item)*(Percent of Revenue/100)

Type	Value		Per piece/order	Calculation
Purchasing and acquisition (P&A) costs	Percent of Revenue	P&A costs in Rand from Table 7.3	P&A cost per purchase item	Percent of Revenue = [(P&A costs in Rand from the formula used in Table 7.3)/Revenue]*100 P&A cost (Rand) per purchase item = (Rand per purchase item)*(Percent of Revenue/100)
Planning Costs	Percent of Revenue	Planning costs in Rand from Table 7.3	Planning cost per (order and purchase) item	Percent of Revenue = [(Planning costs in Rand from the formula used in Table 7.3)/Revenue]*100 [Planning cost (Rand) per (purchase and order) item = (Rand per purchase item + Rand per order item) * (Percent of Revenue/100)
Operating Margin (OM) Impact (%)				
	Add all the Percent Revenue (OM %)			Calculate impact (%) for test scenario as follows: OM Impact (%) = | [OM % (Test Scenario)] – [OM % (Base Case)]|
Operating Margin Impact (Rand)				
		Add all the costs (OM in Rand)		Calculate impact (Rand) for test scenario as follows: OM Impact (Rand) = | [OM Rand (Test Scenario)] – [OM Rand (Base Case)]|

Once the opportunity spreadsheets have been calculated for each problem statement, the opportunities per problem statement are prioritised using a priority opportunity matrix (Bolstorff and Rosenbaum, 2003: 140). The matrix works as follows: on the Y-axis of the matrix the Business Impact (Small Payoffs and Big Payoffs) are given in blocks of 10 for each, gradually moving from very small payoffs, switching from small to big and ending at very big payoffs. The X-axis gives ease of implementation (Easy and Tough) using the same principle as for small and big payoffs). Using Table 7.11, the Operating Margin Impact (Rand) can be calculated to determine whether solving the problem will have a big or small payoff. The rest is done subjectively and by consensus. Figure 7.4 shows the matrix.

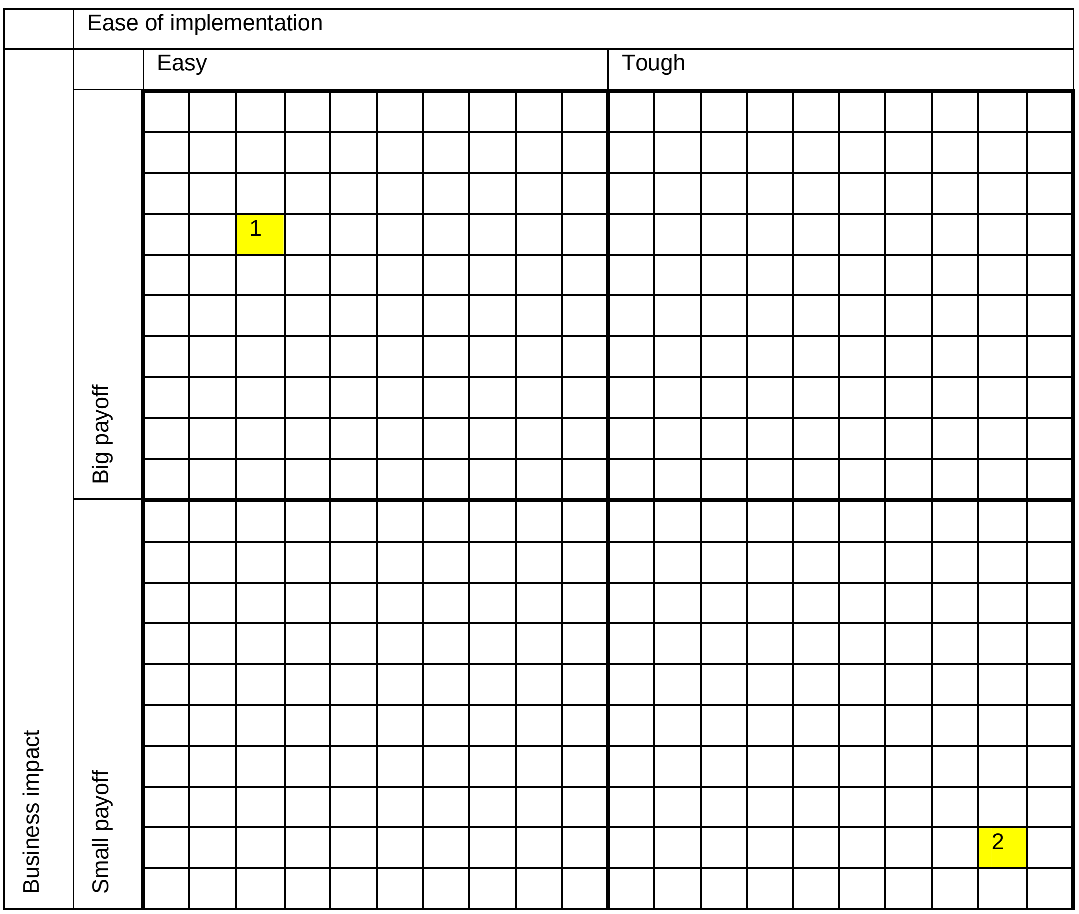

Figure 7.4: The opportunity priority matrix

In this matrix, solving Problem Statement 1 is very easy and has a big payoff for the GIS unit, but solving Problem Statement 2 is going to be very difficult (tough) and it will yield a small payoff. Both need to be solved, but it would be good practice to implement the changes indicated in Problem Statement 1 first and then 2, unless 2 has to be done first to enable the successful changes in 1. In setting up this matrix, a decision can be made to exclude some of the problem statements. Some of the problem statements can be excluded due to the lack of information that still needs to be collected to understand the nature of the problem fully. Table 7.12 gives an overview of operating margin impacts for each problem statement (fish).

Table 7.12: Operating margin impact summary

Problem Statement	**Operating Margin Impact (Rand)**
Problem Statement 1	
Problem Statement 2	
Problem Statement x	
Total Impact (Rand)	

The next section looks at where in the SCOR Level 2 processes the changes can be made and the mapping of the AS IS Level 3 processes, indicating where the changes can be implemented in the Level 3 process and mapping of the TO BE flow.

7.2.6 Improving the chain

This section looks at the AS IS (the current supply chain) and the TO BE (the future supply chain) processes to address the problems identified in the previous sections. This section starts with mapping of the areas of improvement using the GISDataSCOR (GDS) Level 2 process categories. This is used as a guide for the GDS Level 3 process element mapping of the supply chain. The GDS Level 3 is first used to map the supply chain as it is currently. The information gathered during this process will then be used to improve the supply chain by mapping the future supply chain using GDS Level 3 process elements.

7.2.6.1 Mapping areas of improvement

Use the AS IS SCOR Level 2 map as developed in the process discussed in Section 7.2.3 and indicate where the changes can be implemented and what the changes are based upon, utilising the problem statements shown in Figure 7.5. This is used as a guide when mapping the GDS Level 3 AS IS supply chain for the various process elements given in the GDS user guide (Schmitz, 2006).

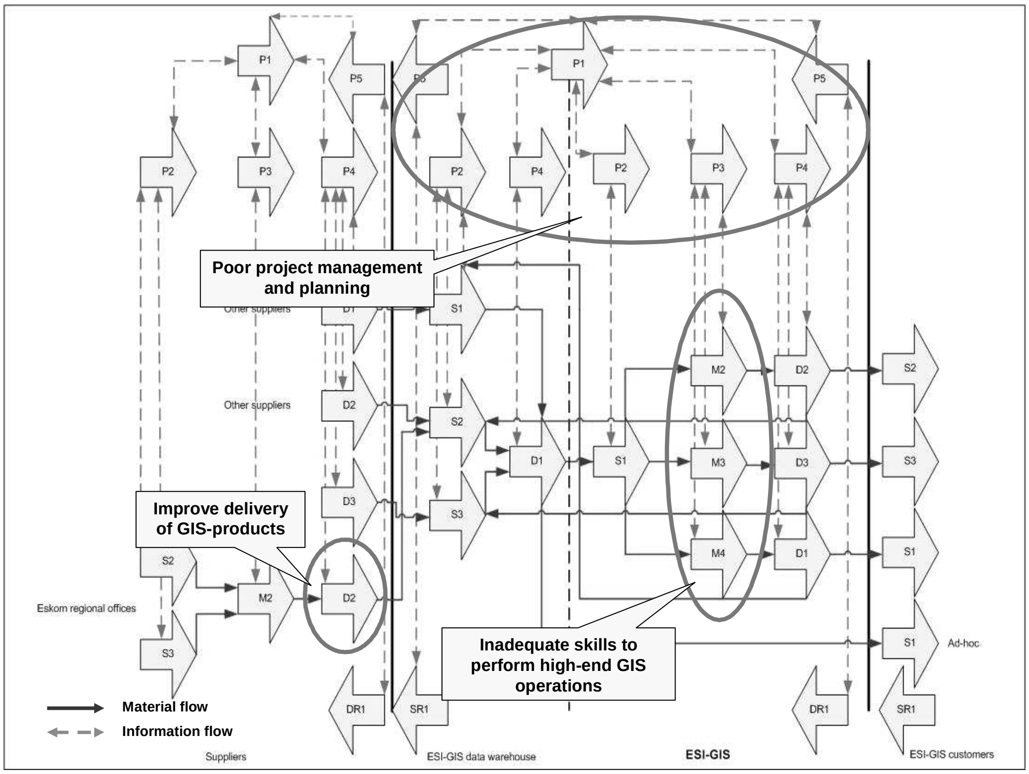

Figure 7.5: Indicating the changes using GDS Level 2 process flows

7.2.6.2 Analysing and mapping the AS IS supply chain at GDS Level 3

In this phase the supply chain is analysed in depth, and consists of two steps. The first step is to map the current supply chain known as the AS IS supply chain, using a SWIM diagram. A SWIM diagram resembles a competition swimming pool with designated lanes for each competitor (Bolstorff and Rosenbaum, 2003). In the context of supply chain analysis, each department or function is assigned to a lane. The GDS Level 3 process elements are placed in the appropriate lanes, for example S1.1 (*Schedule product deliveries*) is placed in the supplier lane (Figure 7.6), whereas S1.2 (*Receive product*) and S1.3 (*Verify product*) are located in the Function/Department 1, which carries out the procurement function for the GIS unit. S1.4 (*Transfer product*) is placed in the lane that manages the data and/or the data warehouse (Function/Department 2 in Figure 7.6).

If two or more lanes share the same process element or process category (such as P1, P2, M1, etc.), the process element or the process category is placed across the different lanes if they are next to each other or they are placed in each lane respectively as demonstrated in Figure 7.6. The second step is the “Staple-yourself-to-an-order” analysis using the workbooks as discussed in Section 5.2.

The data collected when doing the GDS Level 3 analyses using the different workbooks are collated in a spreadsheet to provide an overview of the supply chain’s performance with regard to the different metrics and performance categories. These can be scaled up to GDS Level 2 and GDS Level 1. Figure 7.7 gives an example of such a spreadsheet. This spreadsheet is used in conjunction with the AS IS GDS Level 3 mapped supply chain. The GIS unit now has an understanding of how its supply chain looks and how the supply chain is performing.

The disconnect information that has been collected in this phase is linked back to different causes and sub-causes that have been identified in each problem statement, thus providing the GIS unit with information on where in the supply chain the problems are located which must be rectified to improve the supply chain. Using this information, the GIS unit can now plan the improved supply chain which will be discussed in the next section.

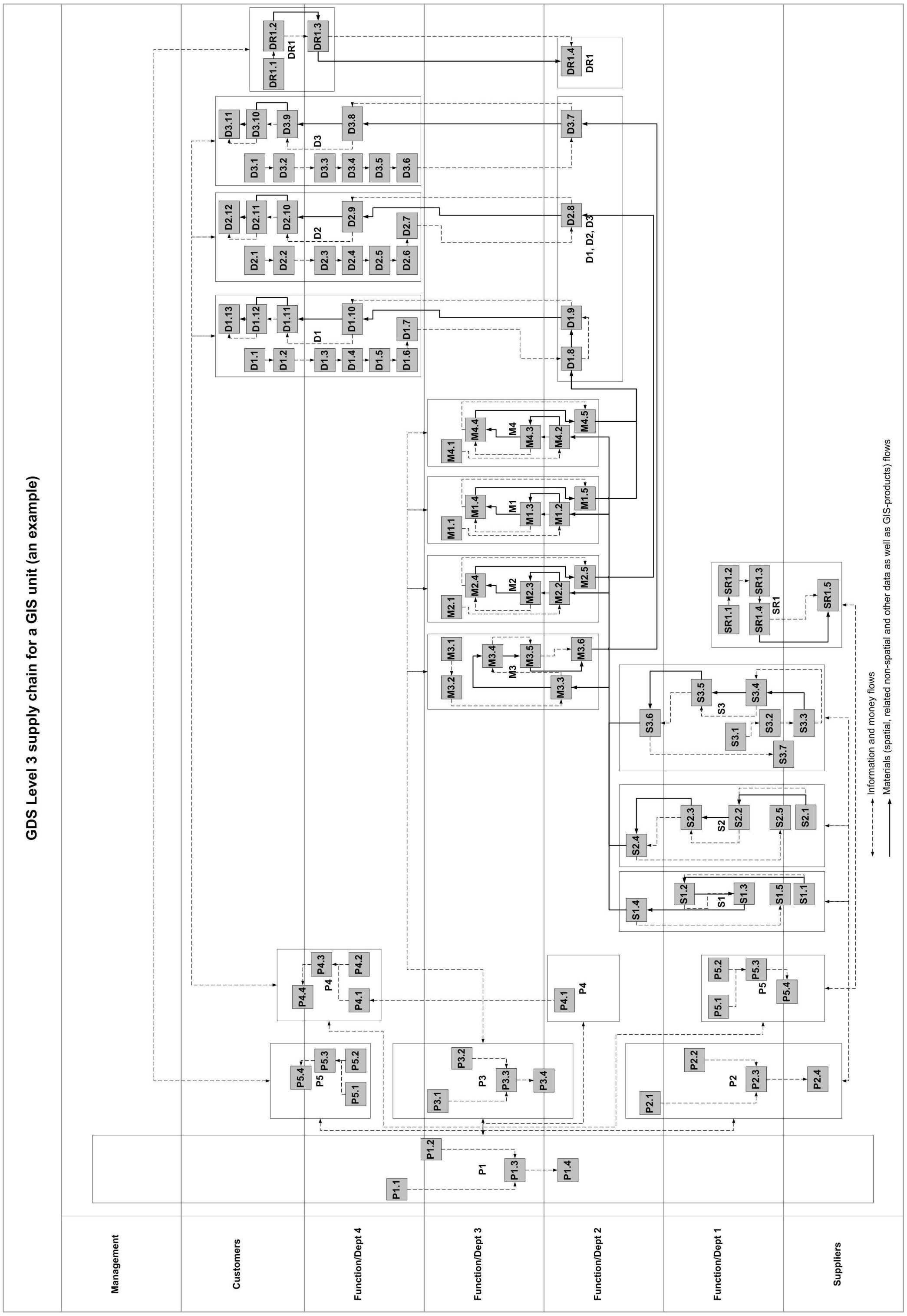

Figure 7.6: A SWIM diagram showing different functions, process categories and process elements

7.2.6.3 Mapping the TO BE supply chain at GDS Level 3

Based on the above information, a GIS unit might decide to improve the supply chain by adding, reducing or keeping the swimming lanes and repositioning the process categories and process elements with regard to their position in the various swimming lanes. This is a procedure suggested by Bolstorff and Rosenbaum (2003). Once the TO BE supply has been identified and agreed upon, the problems that have been identified in the previous phase are indicated in the TO BE supply chain.

The next step is to use the TO BE supply chain and the identified problem areas to set up a strategy to improve the supply chain. One method is to prioritise the identified problems by using the ABC analysis which uses the Pareto principle. The Pareto principle is used to identify those activities that utilise 20% of an organisation's resources but have an 80% impact on its output, or from a supply chain point of view, it is the 20% of your stock that makes up 80% of sales (Vogt, Pienaar and de Wit, 2005). With regard to prioritising the identified problems, the ABC analysis can be utilised to identify the 20% of the identified problems that will bring about an 80% improvement to the supply chain in relation to the set target (i.e. a 10% reduction in labour cost). These problems are classed as A-class problems. The B-class problems are those 50% of the identified problems that if solved will bring about a 15% improvement to the supply chain. The remaining 30% of the problems are those whose solutions will only bring about a 5% improvement, and are classed as C-class problems. The impact of solving these problems can be ascertained from the workbook spreadsheet as shown in Figure 7.7. Based on the result of the above analysis, a GIS unit can then link a time frame to solving these problems, which in turn will improve the efficiency and effectiveness of the supply chain.

1														
2	MAKE													
3	**Performance Attribute**	**Metric**	**Make to Stock**						**Make to Order**					
4			M1.1	M1.2	M1.3	M1.4	M1.5	**M1**	M2.1	M2.2	M2.3	M2.4	M2.5	**M2**
5	*Reliability (aim 100%)*	Schedule achievement % on time	80						100					
6		Inventory accuracy		0						0				
7		Fill rates %			90									
8		Ratio of actual to theoretical cycle time %			67						75			
9		Warrenty and returns (% not returned by customer)			90						90			
10		Placement time of GIS-product in data warehouse				30						30		
11		Percent of orders scheduled to customer request date							100					
12		Number of model changes before model finalisation****												
13		**Production reliability (%)**						**60**						**66**
14	*Responsiveness (as quick as possible)*	Data warehouse accessibility (days)*		1						1				
15		Total built time (days)			90						30			
16		GIS-prtoduct change over time			10						10			
17		Release process cycle time					2						2	
18		Production engineering time (days)												
19		**Total production cycle time to completion (days)***						**103**						**43**
20	*Flexibility (as fast as possible)*													
21	*Costs (as low as possible)*													
22		Scheduled resource costs	R 49 318.73						R 230 154.08					
23		Total production employment			R 147 956.19						R 24 659.36			
24		Value added employment productivity			R 157 819.93						R 36 989.05			
25		Warranty costs			R 98 637.46						R 24 659.36			
26		Release costs***					R 0.00						R 0.00	
27		Model changes costs												
28		**Production costs**						**R 453 732.31**						**R 316 461.85**
29	***Assets***	Capacity utilisation %	16		59			**38**	16		65			**41**
30		Cash-to-Cash cycle time (assumption 1)**		1516				**1516**		1516				**1516**
31		Cash-to-Cash cycle time (assumption 2)**		161				**161**		161				**161**
32														
33														
34	**Comments**													
35	* Includes searching for data on RHD, DVD or CD-ROM													
36	** From ESI-GIS SCORcard													
	*** Not available, currently part of													

Figure 7.7: Example of a GDS Level 3 data spreadsheet

When mapping the GDS Level 3 AS IS and the TO BE supply chains, the various enabling processes are not mapped so as not to over-complicate the mapped supply chain. When improving the supply chain using the TO BE supply chain at GDS Level 3 process element level, the enabling processes are identified at each process element using either the GDS model manual or the workbooks where the enabling process is indicated in the input and output fields of the table given for each process element. These enabling processes are then used when improving the supply chain at the relevant process element as described above.

The final phase of the methodology is the presentation of all the above analyses in a report format as well as the prioritised disconnects to provide a basis for guiding the supply chain improvement process using supply chain management.

7.2.7 Shortcomings and possible sources of error

The major shortcoming identified was that there were currently no data available or readily available to benchmark the GIS unit against its competitors as required by the SCORcard part of the methodology. The second shortcoming identified was that the GIS unit might not have had all the information available to populate the SCORcard as well as some of the Level 3 metrics of both the SCOR and GDS model. The reason for this shortcoming was that the GIS unit did not plan to collect this required type of data. The third shortcoming was the unfamiliarity by the GIS unit's staff members of supply chains and supply chain management. The methodology makes provision for introducing staff members to supply chains and supply chain management as well as the five management processes of the SCOR and GDS models, which should address to a certain extent this shortcoming. Further familiarisation with supply chains and supply chain management will occur when the data for the Level 3 process elements is collected.

A possible limitation of this study is that only a single GIS unit was selected to demonstrate whether supply chains and supply chain management could improve the unit's effectiveness and efficiency in producing a GIS product. The reason for selecting only one GIS unit has been given in Section 7.2.1. A further limitation is that the use of a single GIS unit could lead to possible bias in the results for reaching the objective of this study. It is expected that by using the described methodology based on Bolstorff and Rosenbaum (2003) as well as the SCOR and GDS models, any possible bias in the results will be reduced.

The following possible errors in the data and data collection have been identified:

- Double counting with regard to costs involved to execute identified process elements.
- Misunderstanding of metrics which could result in the wrong data being provided.
- Data capturing errors of quantitative and qualitative data during face-to-face interviews and the transferring of data from the workbooks and financial statements.

7.2.8 Conclusions

This section discussed the research design and the methodology utilised to analyse the supply chain of a GIS unit using firstly the SCOR model and secondly the GISDataSCOR (GDS). It is a comprehensive methodology utilising all three levels of the GDS model, which then provides the basis on which a GIS unit can improve its supply chain by managing the supply chain's performance and solving the identified problems. This section also indicated possible shortcomings, limitations and errors that might be encountered during the research phase of this study. The rest of this chapter describes the data collected as well as the results of the data analysis of each study in order to achieve the objective of this study.

7.3 The use of supply chain management and SCOR at ESI-GIS: the 2004/5 study

In Section 7.2 the methodology was provided to analyse a GIS unit's supply chain. Two studies were done at ESI-GIS. The first was done in March 2005 using this methodology and the standard Supply-Chain Operations Reference (SCOR) model as published by the Supply-Chain Council. The CSIR is a registered member of the Supply-Chain Council, and thus has full access to all tools published by the Council. The SCOR model used in this study was SCOR Version 5.0 which was published in 2001. The second study was done in the 2006/7 financial year starting in October 2006 and ending in May 2007 using the adapted SCOR model, namely GISDataSCOR (GDS).

This section examines the application of the SCOR model to ESI-GIS in the 2004/5 financial year. In the 2004/5 study, ESI-GIS was located within Eskom Distribution, and is now located as a unit under Resources and Strategy, a corporate division of Eskom. ESI-GIS is currently a cost centre with the aim of making a profit (van der Walt, 2006a). Eskom Distribution is responsible for the distribution of electricity to municipalities, industry, agriculture as well as some households. Other functions of Eskom Distribution are the expansion and maintenance of the high and medium-voltage network as well as the substations. ESI-GIS provides GIS products to Eskom Distribution to assist with their mandate. For the spatial data GIS product range, ESI-GIS sources data from various sources, creates the different GIS products and delivers these products to clients. The first part of the methodology discussed in Section 7.2 looks at the business context of ESI-GIS, which for the purpose of this research was discussed in Chapter 6 as part of the study area discussion of this research and applies to both studies. The discussion starts with the supply chain definition matrix for the 2004/5 study, followed by the performance and benchmarking phase of the methodology. This section is based on an internal CSIR report published by the researcher in March 2005: *Using supply chain management for ESKOM Distribution GIS Unit.* CSIR Technical Report 2005/25, CSIR, Pretoria, South Africa (Schmitz, 2005).

According to Table 7.13, the ESI-GIS supply chain definition matrix consists of four different GIS product ranges, namely spatial data, standards for automated mapping and facilities management (AM/FM), early warning systems and spatial modelling. Most of ESI-GIS's work is done in the spatial data and spatial modelling product range, and according the methodology discussed in Section

7.2, a selection should be made as to which product range the supply chain analysis will apply. However, since ESI-GIS is a small GIS unit, it was decided to analyse the supply chain which included all these various products, since it was difficult separate the financial aspects from the different product ranges. Standards for AM/FM have been discussed in Section 6.6.2.

Table 7.13: Supply chain definition matrix

SC definition matrix	**Geography of customers/market channel**	
Product	SA government departments	SA parastatal organisations
Spatial data	X	X
Standards for AM/FM		X
Early warning systems		X
Spatial modelling	X	X

The spatial data GIS product range consisted of:

- Roads/addresses, showing the electricity connections and other assets at street address level.
- Electrification areas, i.e. areas that are currently served by Eskom Distribution.
- Basic Eskom maps, showing cadastre information, topography and the electricity network and areas of interest to Eskom as well as to government.
- EDI Holdings, maps indicating areas of interest, transmission lines and other assets such as substations.
- Demand side management (DSM) data consisting of transmission lines, distribution networks and assets.

7.3.1 Performance and benchmarking

This section looks at ESI-GIS performance using the SCORcard as discussed in Section 7.2.2. There was and still is currently no benchmarking data available to benchmark the performance of ESI-GIS against that of other GIS units. At the time of this study, ESI-GIS operated in a non-competitive environment; it was then decided to concentrate on performance as a guide to improve the supply chain. Tables 7.3 and 7.4 in Section 7.2.2 give the method of how to populate the SCORcard. Table 7.14 below gives the SCORcard for ESI-GIS. The values that were used in the analysis were the actual and confirmed values that were available to ESI-GIS as on 31 January 2005 (de la Rey, 2005). The shaded areas that are based on the benchmarking exercise are excluded from this study.

Table 7.14: The SCORcard for ESI-GIS spatial data products (2004/5 study)

	Performance Attribute / Category	**Level 1 Performance Metric**	**Actual**	**Parity (P)**	**Advantage (A)**	**Superior (S)**	**Parity Gap (Actual – Parity)**	**Requirements Gap (Actual – P or A or S)**	**Opportunities**
Customer facing	Supply Chain Delivery Reliability	Delivery Performance	80/103=**77%**						
		Perfect Order Fulfilment	43/103=**43%**						
	Supply Chain Responsiveness	Order Fulfilment Lead Time	Less than 3 days **64%**						
			More than 3 days **16%**						
			20% of jobs long-term fixed on a year to deliver						
	Supply Chain Flexibility	Supply Chain Response Time	Not available, a risk that must currently be addressed						
Internal facing	Supply Chain Costs	Costs of goods (Costs of goods sold – COGS)	R2 067 000/ R4 163 000 = **50%**						Reduction of 5% in labour costs
		Total Supply Chain Management Costs	R1 063 000 / R4 163 000 = **26%**						
		Sales, General and Administration Costs (SG&A Costs)	R1 033 000 / R4 163 000 = **24%**						

	Performance Attribute / Category	Level 1 Performance Metric	Actual	Parity (P)	Advantage (A)	Superior (S)	Parity Gap (Actual – Parity)	Requirements Gap (Actual – P or A or S)	Opportunities
		Returns Processing Costs	Not available, a risk that must currently be addressed						
	Supply Chain Asset Management Efficiency	Cash-to-Cash Cycle Time	Due to the payment structure not available/ applicable						
		Inventory Days of Supply	Not available						
		Asset turns	Not available						
Shareholder facing	Profitability	Gross Margin	**50%**						
		Operating Income (Margin)	**23%**						
		Net Income (Net Operating Income)	Taxes not available						
	Effectiveness of Return	Return on Assets	Not available						

From the above table, the following it can be concluded that ESI-GIS delivered 77% of its orders in full, meaning that they were supplied to the customer at the time determined with the customer, but only 43% of all the orders were perfect orders. A perfect order as indicated by the Supply-Chain Council (2001) is an order that is delivered in full and error free at the right time, and that the accompanying documentation such as invoices and metadata are correct.

With regard to order fulfilment, ESI-GIS has three distinct groups: those orders that are shipped within three days and are mostly ad hoc projects. They consist of downloading existing data such as the distribution electricity network onto a CD-ROM or DVD and shipping them to the customer (de la Rey, 2005). They formed the bulk of ESI-GIS's spatial data GIS product workload. The spatial data GIS products where the order fulfilment times were longer than three days but less than a year were those GIS products that needed to be updated first and then sent to the customers. The main customers are the Eskom regional offices, which use the data for planning and operational purposes using AM/FM software (de la Rey, 2005). The projects that were scheduled for a year were projects that ESI-GIS carried out to create base data sets specifically for Eskom's use, such as the creation of a GIS product that shows the electricity connections at street address level. These data sets are then made available to the Eskom regional offices for planning purposes (de la Rey, 2005).

The Costs of Goods Sold (COGS) comprises 50% of ESI-GIS costs and consists of direct and indirect labour costs as well as the purchase of data from suppliers. Customer service costs, information technology infrastructure costs, purchasing and acquisition costs and planning costs were added up to provide the total supply chain management costs, which was 26% of the income that ESI-GIS received at the end of January 2005. ESI-GIS saw an opportunity to reducing the labour costs by 5% by improving the skills of its staff. This opportunity was reflected in the opportunity analysis that was based on the disconnect analysis. Before the opportunity analysis could be done it was necessary to understand ESI-GIS's data flow analysis at SCOR Level 2.

7.3.2 AS IS material flow processes and performance measurements

This section explores the AS IS material flow mapped at SCOR Level 2 as well as the SCOR Level 2 process categories involved. It also looks at the material flow performance, which was not done owing to the non-availability of the required information. This performance analysis was excluded from the study. The material flow is mapped next.

7.3.2.1 Mapping the material flow

The material flows from ESI-GIS's suppliers to ESI-GIS and from ESI-GIS to its customers are shown in Figures 7.7, 7.8 and 7.9 (de la Rey, 2005). The proprietary data sets are sourced from the Eskom regional offices, and are then used to update ESI-GIS spatial data sets such as the electricity network and substations. Core data sets are mostly sourced from government institutions such Chief Directorate: Surveys and Mapping and Stats SA (de la Rey, 2005).

Depending on the size of the spatial, related non-spatial and data sets and the GIS products created by ESI-GIS, they are either loaded onto a removable hard disk, DVD or CD-ROM. In some instances ESI-GIS printed a paper map that is shipped to ESI-GIS's customers as shown in Figure 7.9 (de la Rey, 2005).

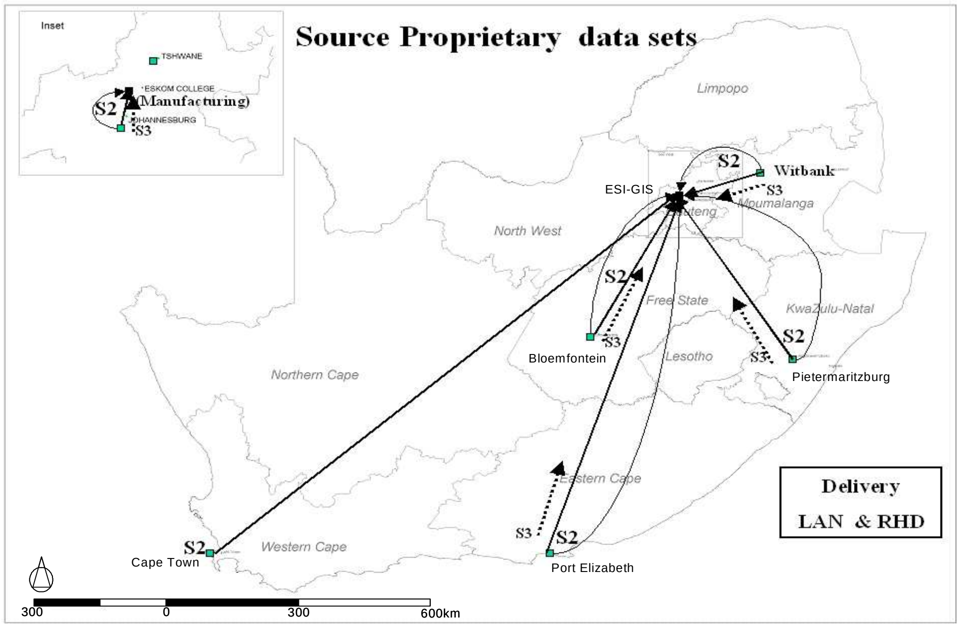

Figure 7.7: Sourcing proprietary data sets (RHD = Removable Hard Disk)
(from De la Rey, 2005)

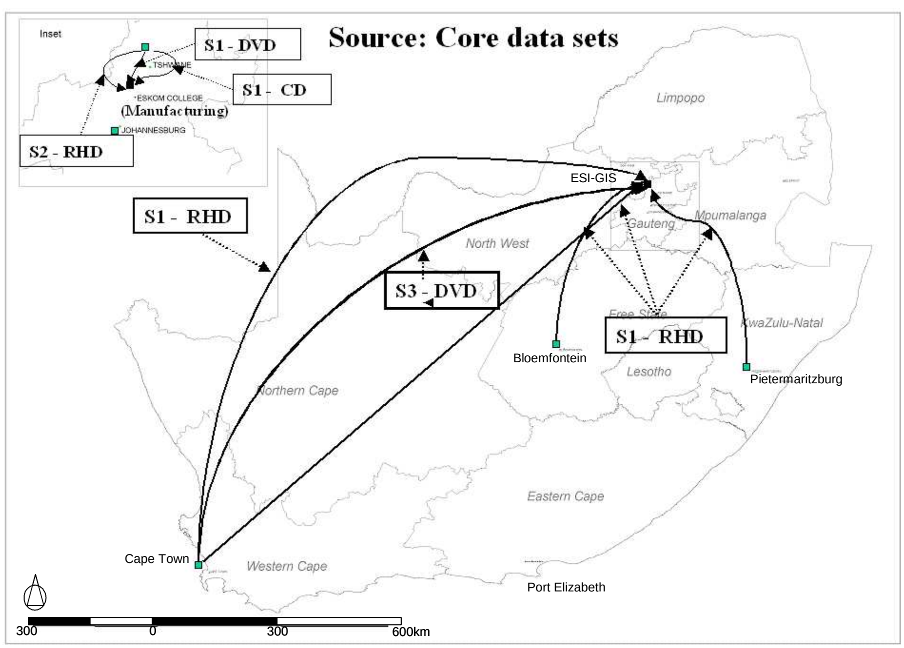

Figure 7.8: Sourcing of core data sets

(from De la Rey, 2005)

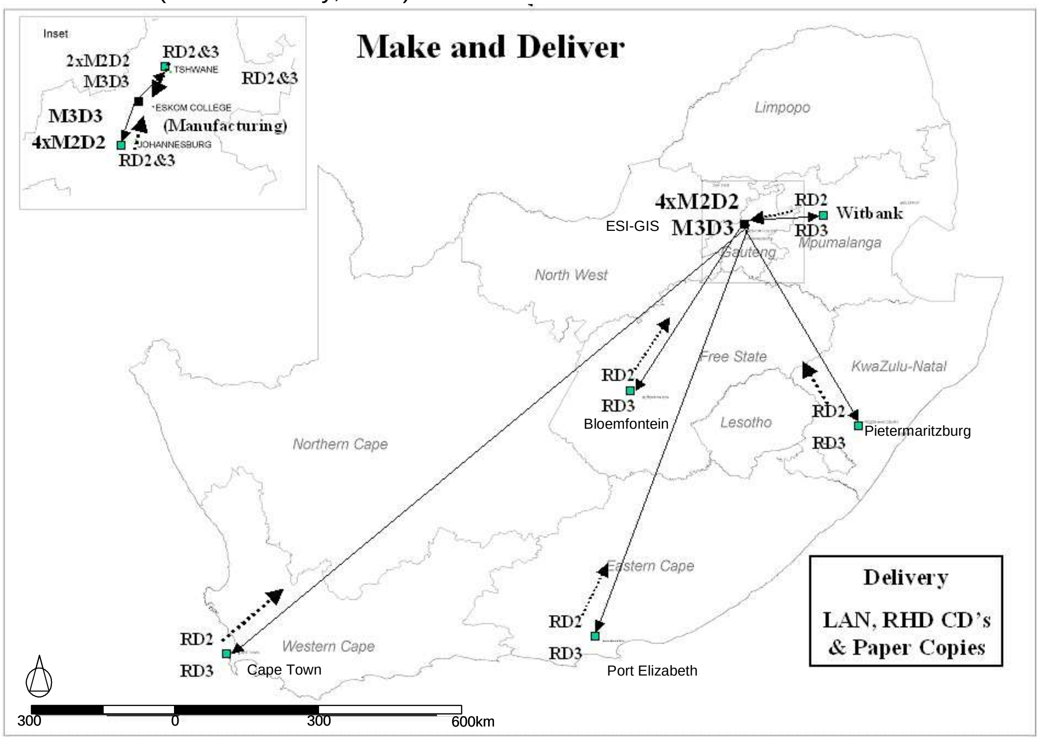

Figure 7.9: MAKE and DELIVER processes

(from De la Rey, 2005)

The RD description in Figure 7.9 indicates that the regional offices have to return the delivered GIS products as value-added data back to ESI-GIS for further use. Owing to the confusion with the DR (Deliver RETURN) process category in SCOR, the RD description has been omitted from the analysis and replaced with SOURCE.

7.3.2.2 Mapping the processes

Figure 7.10 gives the processes involved in producing the GIS products that are manufactured in the Spatial Data product range. The data are sourced from eight different suppliers as well as the Eskom regional offices, and five GIS products are manufactured by ESI-GIS. The data obtained from these eight sources are either stocked items such as the data from the Chief Directorate: Surveys and Mapping, Make-to-Order items such as satellite imagery for the Satellite

Applications Centre at Hartbeeshoek and Engineer-to-Order items such as Digital Elevation Models from Geomap in Cape Town.

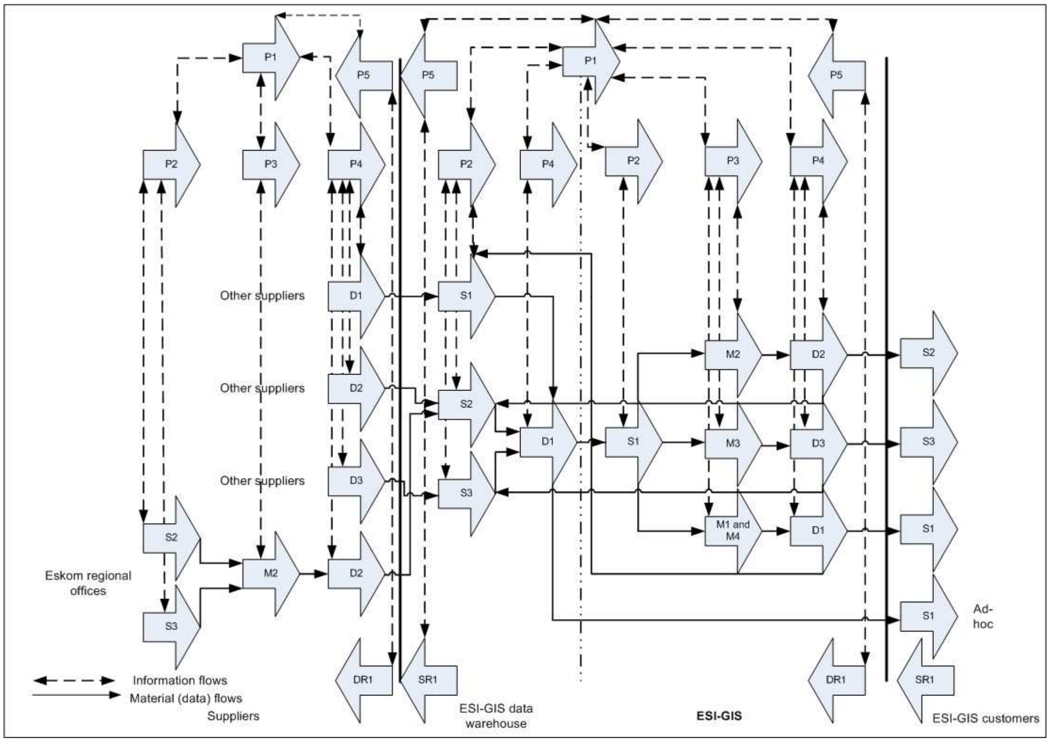

Figure 7.10: Mapping the processes

These are shown as "Other suppliers" in the materials flow diagram in Figure 7.10. The sourced data are stored in a data warehouse from where the data are sourced during the manufacturing. The completed GIS product is then stored in the data warehouse and accessed when the customer needs it.

Table 7.15 provides the core data sets that are used by ESI-GIS for its spatial data GIS products as well as the suppliers of these core data sets. The weights indicate the importance of the data sets, whereas the values in the rows that show the supplier indicate the percentage share of the core data sets provided to ESI-GIS.

Table 7.15: ESI-GIS core data sets necessary to produce the spatial data GIS product range

Weight	**10**	**10**	**5**	**10**	**15**	**50**
	Cadastral	1:50 000	DEMS	Change detection	Demo-graphics	Network
SG PTA	35					
SG Bloemfontein	15					
SG Pietermaritzburg	15					
SG Cape Town	35					
CDSM Cape Town		100				
Eskom Witbank						20
Eskom New Germany						15
Eskom Bloemfontein						20
Eskom Simmerpan						15
Eskom East London						15
Eskom Cape Town						15
Stats SA Pretoria					100	
SAC Pretoria				100		
Geomap Cape Town			100			

An example is the provision of cadastral data to ESI-GIS where the Surveyor-General in Pretoria (SG PTA) provides 35% of the required data and the Surveyor-General (SG) in Bloemfontein provides 15% of the data. The Eskom offices in the table are the six regional Eskom offices. The regional offices are both suppliers to and customers of ESI-GIS. This section presented the supply chain of ESI-GIS at SCOR Level 2 as well as the different core data sets required to create the spatial data GIS products. The next section uses the above information as part of the disconnect analysis.

7.3.2.3 Disconnect and opportunity analysis

Section 7.2.4 describes the methodology used to conduct a disconnect analysis with the aim of establishing at SCOR Level 1 and 2 possible problems within ESI-GIS's supply chain. On 18 March 2005 a disconnect analysis was done at ESI-

GIS, Colenso Building, Midrand, South Africa. The team that participated in the disconnect analysis were:

- Adri de la Rey (Manager)
- Saydha Hoosen (Officer Information Technology)
- Kevin Lagley (Officer Information Technology)
- Mbengeni Makungo (Officer Information Technology)

Table 7.16 gives the different disconnects as recorded for each of the five SCOR management processes, namely PLAN, SOURCE, MAKE, DELIVER and RETURN. The problems and causes are numbered as follows: for PLAN the identification (ID) is 1, the problems are identified as 1.1, 1.2, etc. and the causes are identified as 1.1.1, 2.1.1, etc. For example, 1.1.1 is the first cause and 1.1.2 is the cause of the problem identified as 1.1 in PLAN.

Table 7.16: The different disconnects as identified by ESI-GIS

SCOR element	ID
PLAN	**1**
Unclear customer requirements (P1)	**1.1**
Customer requirements not clearly understood by ESI-GIS	1.1.1
Customer does not know what their requirements are due to lack of understanding of GIS technology and capabilities	1.1.2
Customer requirements are against regulations	1.1.3
Lack of exposure to client's business environment in order to assist the client to understand their requirements	1.1.4
Scope not clear – influences production requirements, resources and plan (P3)	**1.2**
Scope of the project is not properly written into the project plan, which influences the management of the project	1.2.1
SOURCE	**2**
Poor delivery from suppliers (S1, S2, and S3)	**2.1**
Unwillingness of suppliers to collect data for the product	2.1.1
Data in incorrect data formats	2.1.2
Data not conforming to data standards	2.1.3

SCOR element	ID
Unwillingness of suppliers to supply the required data	2.1.4
Data not delivered on time – delays the production process	2.1.5
Incomplete data – missing data layers and/or attribute data	2.1.6
Lack of knowledge regarding available data sets (S1 and S2)	**2.2**
There is no central database listing all the sources and their data (including contact details) in South Africa. ESI-GIS uses "wrong" data as a proxy and discovers after the project that there is actual data available	2.2.1
No inventory list of own data in ESI-GIS data warehouse	2.2.2
Poor "transportation" (S1, S2, and S3)	**2.3**
Network response is slow in terms of sourcing (downloading) data	2.3.1
Licence agreement problems (S2)	**2.4**
Issues arise after licence agreements have been signed regarding the use of data from supplier, i.e. DME changes rules of usage of aerial photographs that it supplies to ESI-GIS	2.4.1
MAKE	**3**
Slow processing time (M1, M2, and M3)	**3.1**
PC processes are slow	3.1.1
Inadequate skills to do some of the processes (M1, M2, and M3)	**3.2**
Skill to understand different projections such as LO to Geographic to Lamberts, etc.	3.2.1
Not trained to work on new versions of software that has been acquired by ESI-GIS	3.2.2
Insufficient skill to work with SmallWorld	3.2.3
Insufficient skills in basic cartography	3.2.4
Inadequate skills to do some of the process, i.e. ModelBuilder of ArcGIS	3.2.5
DELIVER	**4**
Poor "transportation" (D1, D2, and D3)	**4.1**
Network response is slow to deliver (downloading) data	4.1.1
Some PCs cannot read DVDs that have created by ESI-GIS	4.1.2
CDs not readable by some PCs	4.1.3
Inadequate skills to do some of the processes (D1, D2, and D3)	**4.2**
Customers are sometimes not skilled enough to read the delivered product for further processing	4.2.1
Incorrect data formats (D1, D2, and D3)	**4.3**
Clients want data in a format that is different to that in the policy as agreed upon	4.3.1
Data delivered to clients in incorrect format	4.3.2
RETURN	**5**

SCOR element	ID
Incorrect data formats (DR and SR)	**5.1**
Data received in incorrect formats (2.1.2; 2.1.3 and 2.1.6)	5.1.1
Data delivered in incorrect formats (4.3.2)	5.1.2
Incorrect "media" (DR)	**5.2**
Some PCs cannot read DVDs or CDs cut in a certain format, i.e. multi-session DVDs or CDs written in a directory/file structure format	5.2.1
OTHER	**6**
Archiving of data in ESI-GIS data warehouse	6.1

The above problems were grouped into unique problem statements, which are listed in Table 7.17. The problems identified above and their causes become the cause and sub-causes of the problem statement and are represented using a cause-and-effect diagram (fishbone) as discussed in Section 7.2.4. Figures 7.11 to 7.16 give the cause-and-effect diagram for each problem statement listed in Table 7.17. The advantage of using cause-and-effect diagrams is that they provide an immediate overview of the identified problems and their causes. Table 4.1 in the figure refers to Table 7.16 above.

Table 7.17: Unique problem statements for ESI-GIS

Problem statement	**New ID**	**Old IDs** (in Table 7.16)
Unclear project requirements	1	1.1 and 1.2
Poor data	2	2.1, 2.4, 4.3 and 5.1
Poor inventory lists	3	2.2
Inadequate skills to perform certain tasks	4	3.2 and 4.2
Poor "transport"	5	2.3, 4.1, and 5.2
Poor process performance	6	3.1

Unclear project requirements refer to the problem ESI-GIS experiences when getting a brief from a customer. In such cases the customer has vague GIS product requirements and the ESI-GIS then defines an incorrect project scope, which results in wrong projects being planned to fulfil the customer's need (see Figure 7.11).

A poor data problem statement indicates that data from suppliers are faulty and they do not deliver the data on time. Other data problems are data received are in the wrong format, or that ESI-GIS provides faulty data to the customer. Figure 7.12 gives the cause-and-effect diagram for poor data.

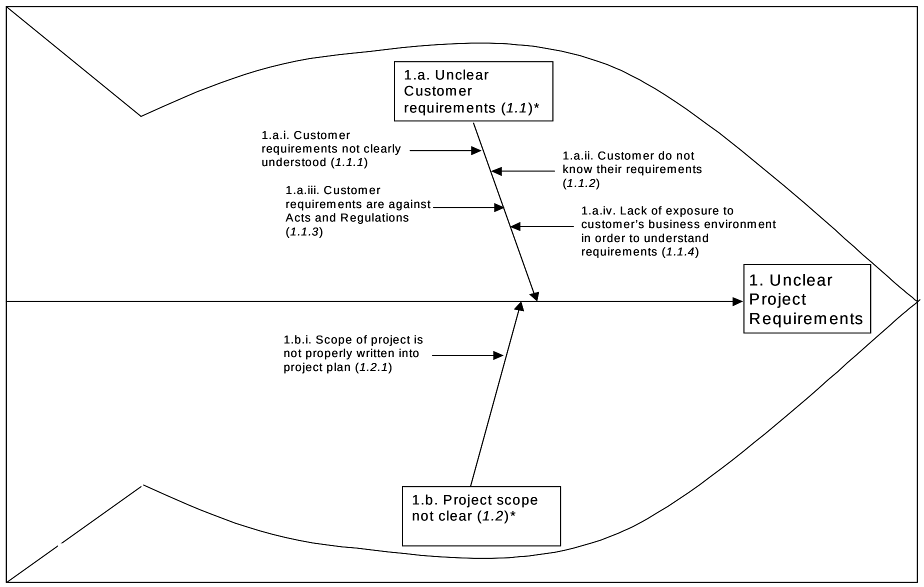

Figure 7.11: Unclear project requirements (*Numbering as per Table 7.16)

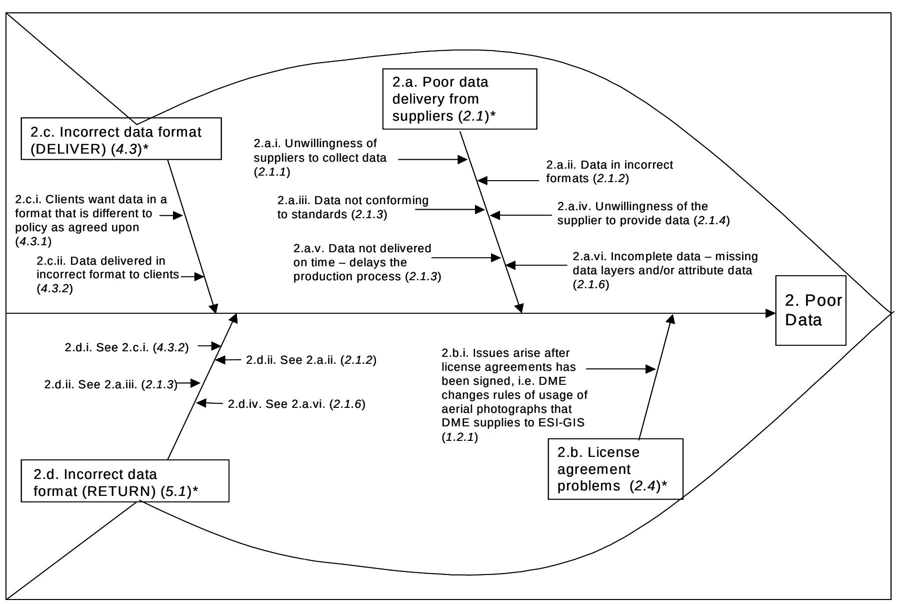

Figure 7.12: Poor data (*Numbering as per Table 7.16)

A poor inventory list indicates that ESI-GIS does not know exactly what data are available and where it is stored. This leads to the acquisition of duplicate data sets, which in turn has a financial impact on ESI-GIS. Figure 7.13 gives the cause-and-effect diagram for poor inventory lists.

Figure 7.14 shows the cause-and-effect diagram for the problem statement of inadequate skills to perform certain tasks. The main skill shortage is that staff, although well trained, lack specific high-end skills for the different GIS software that they use, which leads to cumbersome GIS operations when creating GIS products. Poor transport refers to the movement of data and poor performance relates to outdated hardware used by ESI-GIS (see Figures 7.15 and 7.16 respectively).

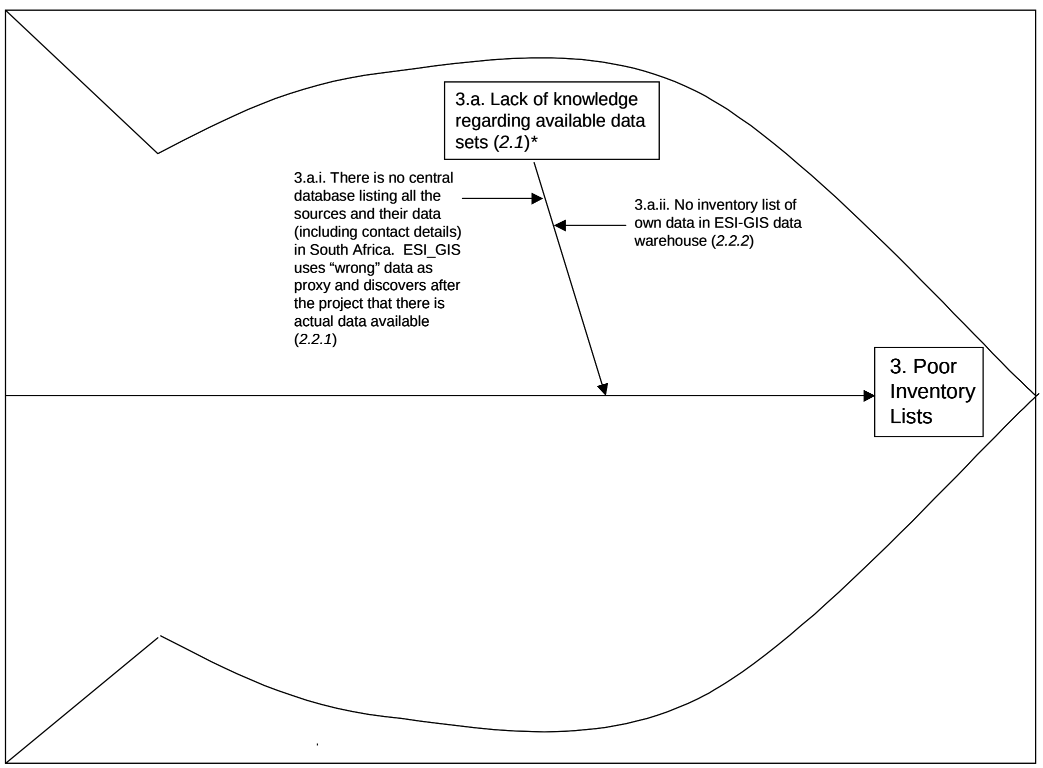

Figure 7.13: Poor inventory lists (*Numbering as per Table 7.16)

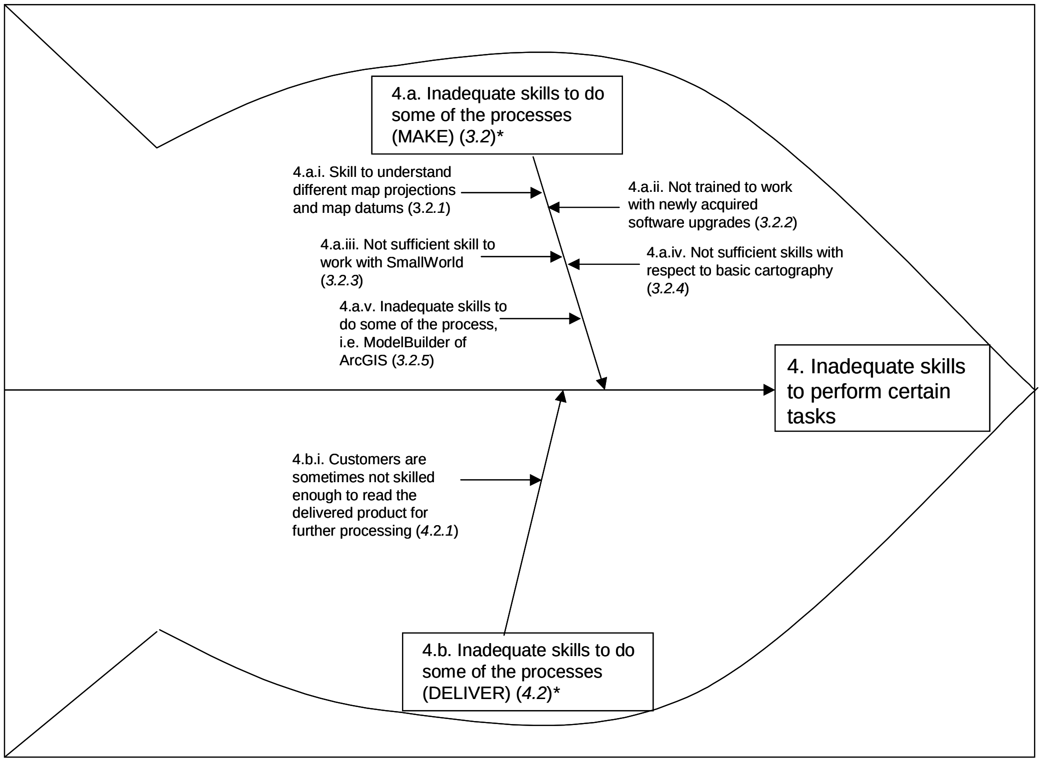

Figure 7.14: Inadequate skills to perform certain tasks (*Numbering as per Table 7.16)

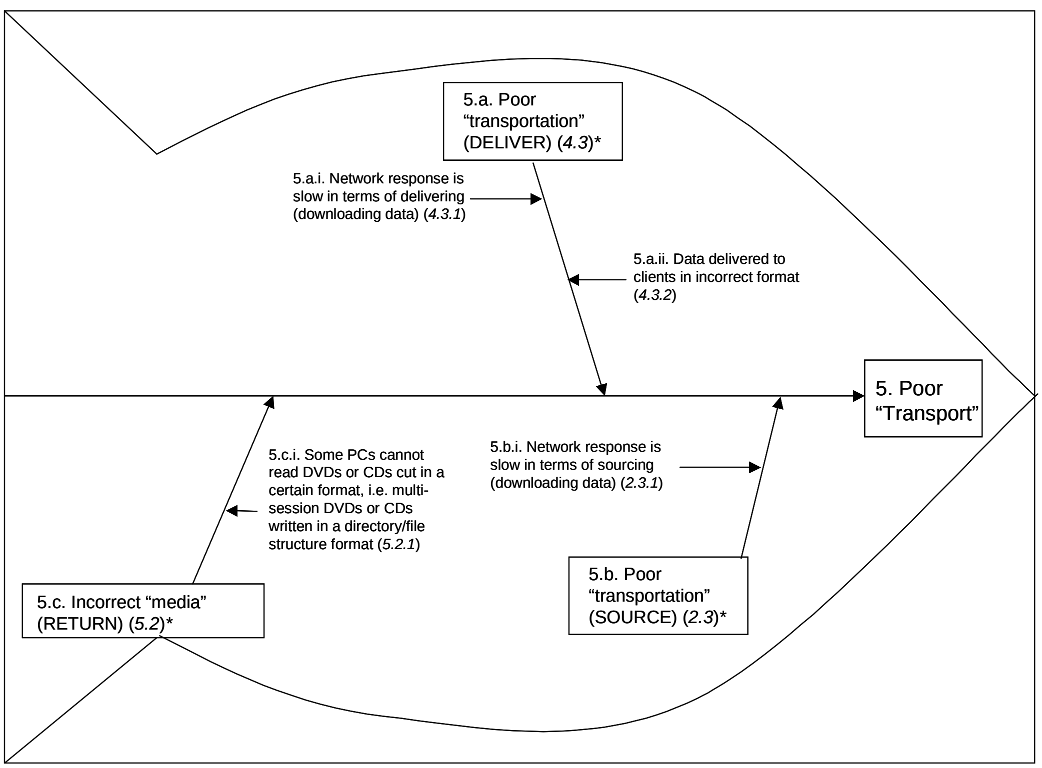

Figure 7.15: Poor "transport" (*Numbering as per Table 7.16)

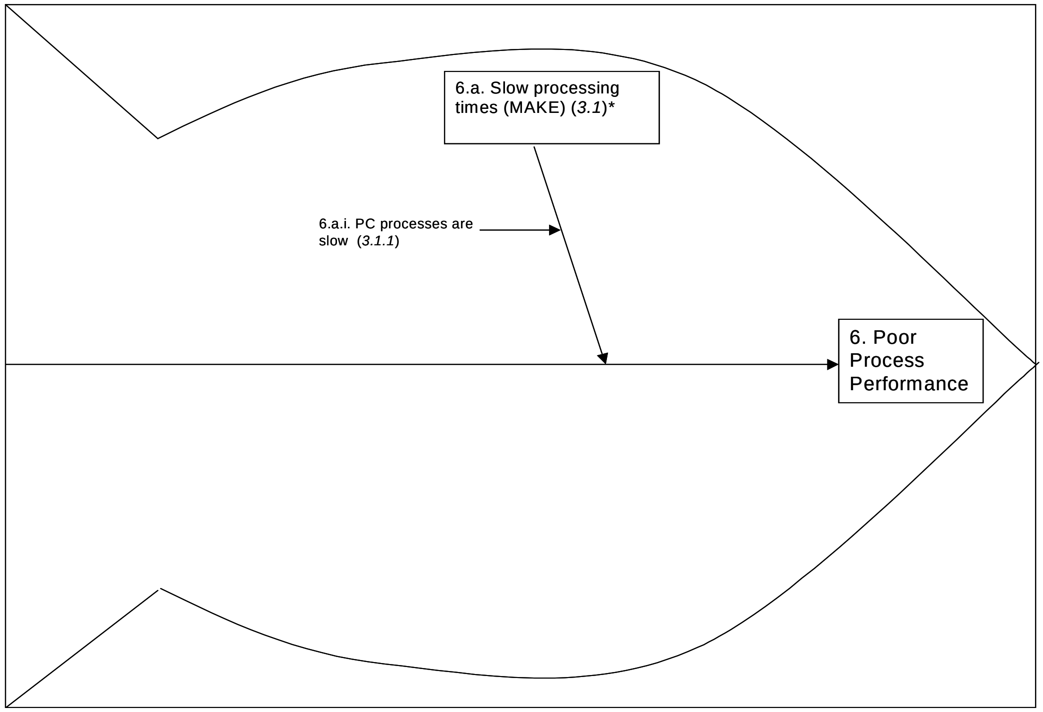

Figure 7.16: Poor process performance (*Numbering as per Table 7.16)

The problems identified above need to be converted into opportunities to improve the supply chain of ESI-GIS. The opportunity analysis process has been discussed in Section 7.2.4. For each problem statement an opportunity spreadsheet was developed to measure the impact on the supply chain when addressing the above problem statements. Figure 7.17 gives an example of such an opportunity spreadsheet. Using the problem statements, a decision must be made as to where in the opportunity spreadsheet the impact will be if the problem is addressed. An example is the 'Inadequate skills" opportunity spreadsheet in Figure 7.17, where it was decided that if the staff skills levels were improved through training, labour costs would be cut by 5%. The opportunity spreadsheet is divided into two sections, the base line and the test scenario section. The base line section contains the actual information and the test scenario section is used to do the what-if analysis. Linking back to the example in the test scenario section where the labour costs are reduced by 5%, the opportunity spreadsheet then calculates the impact on ESI-GIS in monetary value. The impact of reducing the labour costs by 5% is R75 350.00 (see Figure 7.17). The same procedure was followed for the remainder of the problem statements. The opportunity and the impact of the opportunity are reflected in Table 7.18.

Table 7.18: Opportunities and their impacts

Problem statement	Opportunity	Cost savings
Unclear project requirements	Cut planning cost by 20% due to improved project requirements	R73 200.00
Poor data	Cut labour cost by 5% due to improved data, e.g. less time spent on cleaning data	R75 350.00
Poor inventory lists	Cut planning cost by 5% based on the assumption that data can be found more quickly	R18 300.00
Inadequate skills to perform certain tasks	Cut labour cost by 5% due to improvement of skills	R75 350.00
Poor “transport”	None identified	R0.00
Poor process performance	None identified	R0.00
	Total savings	**R242 200.00**

Appendix C contains printouts of all the opportunity spreadsheets applicable to this study. It was decided that the last two problem statements in listed Table 7.18 could not be solved since the transport was dependent on bandwidth availability and the poor performance of the hardware was dependent on the hardware replacement policy of Eskom, which ESI-GIS could not change. These were therefore omitted from the opportunity analysis.

Based on the omission of the last two problem statements, ESI-GIS’s opportunity priorities using the other four problem statements were determined using the Opportunity Priority Matrix as discussed by Bolstorff and Rosenbaum (2003: 140) as shown in Figure 7.18.

Opportunity spreadsheet for ESI-GIS										
			Baseline				**Test scenario**		**Change**	
	Item/Description	Amount/Value [1]	Amount/Value [2]	Per Piece/Order	Comment	Amount/Value [1]	Amount/Value [2]	Per Piece/Order	% Change	Rand ($) Change
1. Transaction summary	Revenue	R 4 163 000.00			Income generated	R 4 163 000.00			0.00	R 0.00
	Orders	8		R 520 375.00	Total number of orders for GIS-product/range type	8		R 520 375.00	0.00	R 0.00
	Total items on orders	41		R 101 536.59	Total number of data layers per order	41		R 101 536.59	0.00	R 0.00
	Purchase orders	103		R 5 436.89	Total number of purchase (data) orders	103		R 5 436.89	0.00	R 0.00
	Total items purchased	555		R 1 009.01	Total number of data layers purchased	555		R 1 009.01	0.00	R 0.00
2. Service level	Perfect Supplier Fulfilment Rate	0.0%			Number of orders the supplier provided the correct data expressed in percent	0.0%			#DIV/0!	
	Perfect Order Fulfilment Rate	43.0%			Number of correct orders given to the client expressed in percent	43.0%			0.00	
	Order Fulfilment Lead Time	0.0			Number of days taken from order to delivery	0.0			0.0	
	Total Item Source Lead Time (Days)	0.0	0.0%		Average days to source a data item (from order date to delivery date)	0.0	0.0%			
		Days	% of total	Number		Days	% of total	Number	Change (Days)	Change (Mix)
	S1 (Source stocked items)	0.0	0.0%	0	Acceptable number of days	0.0	0.0%	0	0.0	0.0
	S2 (Source Make-to-Order items)	0.0	0.0%	0	Acceptable number of days	0.0	0.0%	0	0.0	0.0
	S3 (Source Engineer-to-Order items)	0.0	0.0%	0	Acceptable number of days	0.0	0.0%	0	0.0	0.0
3. Supply Chain costs										
		Amount	Percent of revenue	Cost per piece/order		Amount	Percent of revenue	Cost per piece/order	Change (%)	Change (Rand)
3.1. Production and merchandise costs (COGS)	COGS: Data and Material Costs	R 560 000.00	13.5%	R 1 009.01	Cost of data and material in Rand (as part of the formula in Table 2 to calculate COGS)	R 560 000.00	13.5%	R 1 009.01	0.00	R 0.00
	COGS: Labour costs (direct)	R 1 252 800.00	30.1%	R 30 556.10	Cost of labour (direct) in Rand (as part of the formula in Table 2 to calculate COGS)	R 1 190 160.00	28.6%	R 3 551.60	**5.00**	**R 62 640.00**
	COGS: Labour costs (indirect)	R 254 200.00	6.1%	R 6 200.00	Cost of labour (indirect) in Rand (as part of the formula in Table 2 to calculate COGS)	R 241 490.00	5.8%	R 17 503.70	**5.00**	**R 12 710.00**
3.2. Total supply chain management costs	Customer Service Costs	R 110 000.00	2.6%	R 2 682.93	Customer service cost in Rand (as part of the formula in Table 2 to calculate Total Supply Chain Costs	R 110 000.00	2.6%	R 2 682.93	0.00	R 0.00
	Data warehouse (DW) and IT costs (orders) – Determine the percentage of DW and IT that is used to make the GIS product and determine the cost.	R 220 000.00	5.3%	R 5 365.85	DW and IT costs in Rand [(Total cost)*0.X] Total costs from Table 2	R 220 000.00	5.3%	R 5 365.85	0.00	R 0.00
	Data warehouse (DW) and IT costs (purchases) – Determine the percentage of DW and IT that is used for sourced data	R 220 000.00	5.3%	R 53.32	DW and IT costs in Rand [(Total cost)*0.Y] Total costs from Table 2	R 220 000.00	5.3%	R 53.32	0.00	R 0.00
	Purchasing and acquisition (P&A) costs	R 147 000.00	3.5%	R 0.00	P&A costs in Rand from Table 2	R 147 000.00	3.5%	R 0.00	0.00	R 0.00
	Planning Costs	R 366 000.00	8.8%	R 8 926.83	Planning costs in Rand from Table 2	R 366 000.00	8.8%	R 8 926.83	0.00	R 0.00
		Operating Margin (Rand)	Operating Margin (%)		Add all the costs(operating margin (OM) in Rand; add all the Percent Revenue (OM %)	Operating Margin	Operating Margin (%)			
4. Operating margin impact (Rand and Percent)		R 3 130 000.00	75.19%			R 3 054 650.00	73.38%			
						Impact (Rand)	**Impact (%)**			
						R 75 350.00	**1.81%**			

Figure 7.17: Opportunity spreadsheet for the "inadequate skills" problem statement

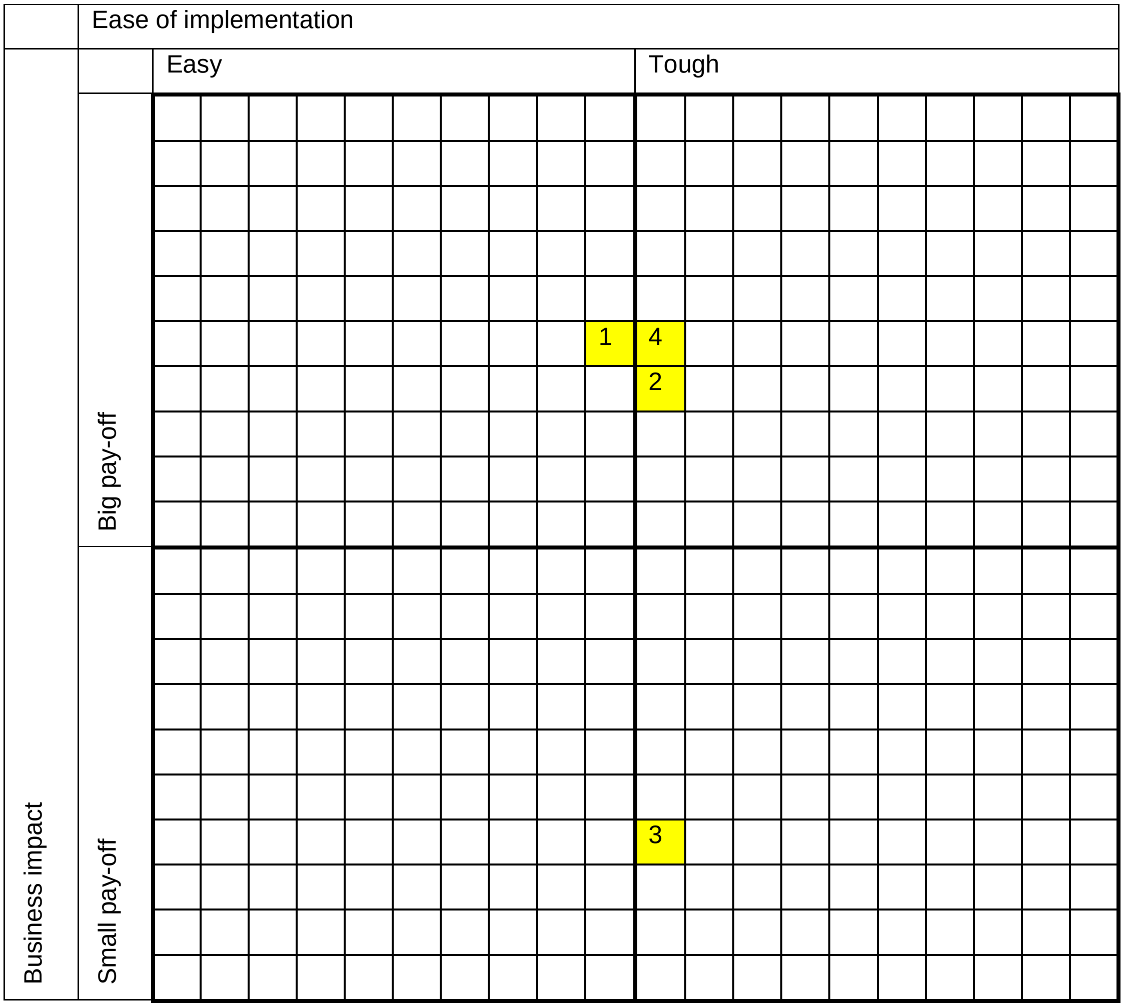

Figure 7.18: ESI-GIS's opportunity priority matrix showing the opportunity for each problem statement

This opportunity matrix will guide ESI-GIS as to when and where in the AS IS supply chain they can make improvements and map the TO BE flow. The numbers in Figure 7.18 correspond to the numbers relating to the problem statement in Table 7.17. Considering this matrix, the faster and more beneficial sequence of addressing the problem statements to improve ESI-GIS's supply chain will be problem statements 1, 4, 2 and 3.

7.3.3 Improving the supply chain of ESI-GIS

This section looks at improving the supply chain of ESI-GIS. According to the methodology discussed in Section 7.2.5, the improvements are indicated by mapping the areas of improvement using the SCOR Level 2 process categories map as shown in Figure 7.10. The second part of the process is to do a SCOR Level 3 AS IS analysis and map the process elements using the SWIM diagram. Using the results of the SCOR Level 3 analysis and the mapped areas of improvement at SCOR Level 2, the TO BE SWIM diagram is developed and the areas of improvements at Level 3 are indicated.

The areas of improvement using SCOR Level 2 were mapped as shown in Figure 7.19, but when the AS IS analysis was done using SCOR Level 3 process elements, it was discovered that the SCOR model as developed by the Supply-Chain Council could not be used as such. It was concluded that to use the SCOR model successfully, it would have to be adjusted for the GIS environment. Adjusting the SCOR model would have been a lengthy process, and it was decided to stop the study at this stage and only show the areas of improvements at SCOR Level 2.

7.3.4 Conclusions

Although the study stopped at mapping the areas of improvement at SCOR Level 2 as indicated in Figure 7.19, it was concluded that the results of the study would provide sufficient input to improve the supply chain by solving the above problem statements. ESI-GIS subsequently put the following programmes in place to improve the supply chain (de la Rey, 2006):

- Unclear project requirements
    - Staff attended a three-month basic course in project management.
    - Formal workshops were held with customers to determine their needs.
    - ISO 9001 was implemented more rigorously.
- Poor data
    - Relationships with suppliers was improved.
    - Internal Eskom suppliers are adhering to internal standards as set out by ESI-GIS.

- In the planning stage: training of internal customers and staff on the data that ESI-GIS has available and the full application of the GIS products, including the limitations of each GIS product.

* Poor inventory lists
  - A dedicated person was appointed in March 2007 to manage the inventory and to establish a data warehouse.
* Inadequate skills to perform certain tasks
  - Project management course as mentioned above.
  - Financial accountancy, owing to the work the GIS staff are required to do: they have to source different data sets from suppliers and cost the project, including delivery, thus necessitating the acquisition of basic accounting skills.
  - Staff attended GIS courses in ESRI and MicroStation. A long-term project is to enable all Eskom users of ESI-GIS to improve their GIS skills as part of their career path development.

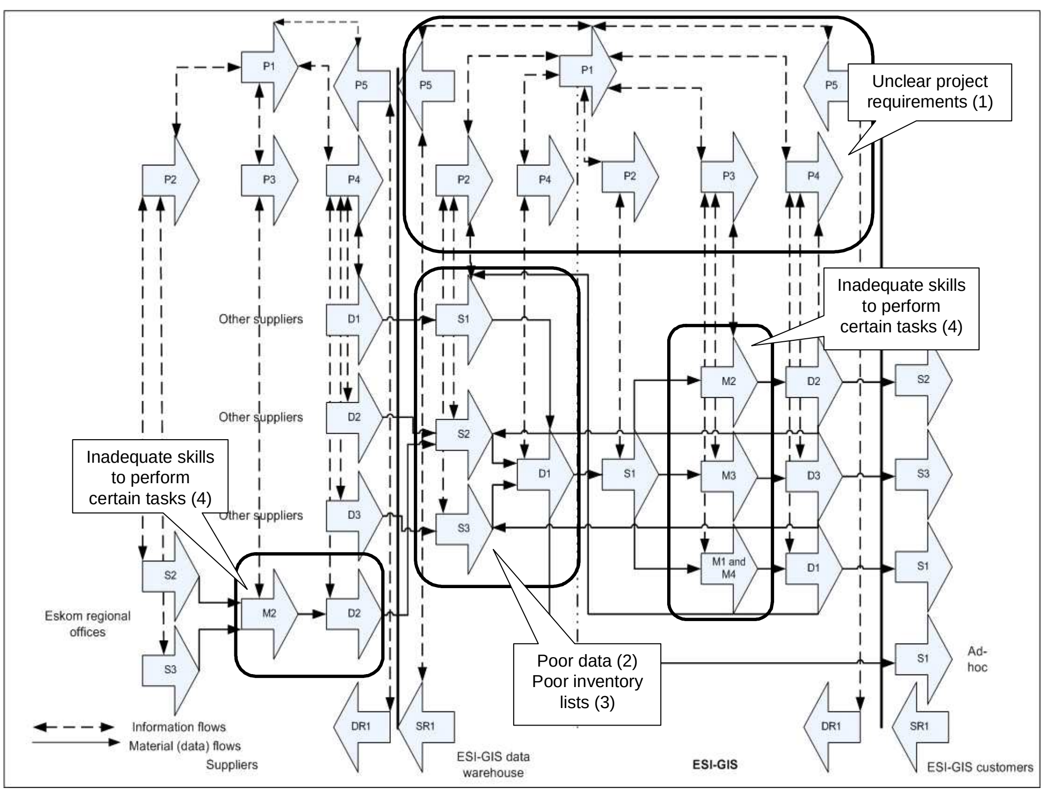

Figure 7.19: Areas where each problem statement has an impact on the supply chain

The second outcome of this study was the development of GISDataSCOR (GDS) model in order to analyse the supply chain of a GIS unit at the process element level (Level 3). GDS has replaced the standard SCOR model in the second study which used the same methodology as discussed in Section 7.2.

It is concluded that, depending on the outcomes of the supply chain analysis, it is sufficient to end the analysis at GDS Level 2 or SCOR Level 2 as used above and make significant improvements to the supply chain without analysing the supply chain at GDS Level 3. Marais (2005) indicated that it is not unusual to stop at a SCOR Level 2 analysis, provided that the improvements based on the information gathered at this stage are significant. The next section discusses the GDS model

7.4 GISDataSCOR

For the purpose of this research, the SCOR model Version 6.1, as published by the Supply-Chain Council (http://www.supply-chain.org) in May 2004, has been adjusted to fit the GIS environment. The original SCOR model terminology has been kept as far as possible with the aim of enabling the Supply-Chain Council to incorporate the model in later versions if so desired, with exception of the **MAKE** Level 2 process category **Maintain-to-Stock** which deals with the maintenance of GIS products. The adjusted SCOR model for the purpose of this research is known as GISDataSCOR (GDS) (Schmitz, 2006). GDS was developed as part of this research using the CSIR's Parliamentary Grant funds and has been published as an internal CSIR report (*GISDataSCOR Version 1.0.* CSIR Parliamentary Grant Report CSIR/BE/CL/IR/2006/0024/B). GDS uses the same three levels as SCOR as discussed in Chapter 2, Section 2.5.2.2, namely the Level 1 management process level which consists of **PLAN**, **SOURCE**, **MAKE**, **DELIVER** and **RETURN**. Level 1 is then broken down into Level 2 process categories, e.g. for MAKE the Level 2 process categories will be M1 (**Make-to-Stock**), M2 (**Make-to-Order**), and M3 (**Engineer-to-Order**). In Chapter 4, Section 4.3.4, the importance of data maintenance and the management thereof was discussed, which necessitated the development of an additional process category, namely M4 (**Maintain-to-Stock**). Figure 7.20 shows all three levels of GDS as well as the flow of information and materials (spatial, related non-spatial and other data) between the various process elements and categories.

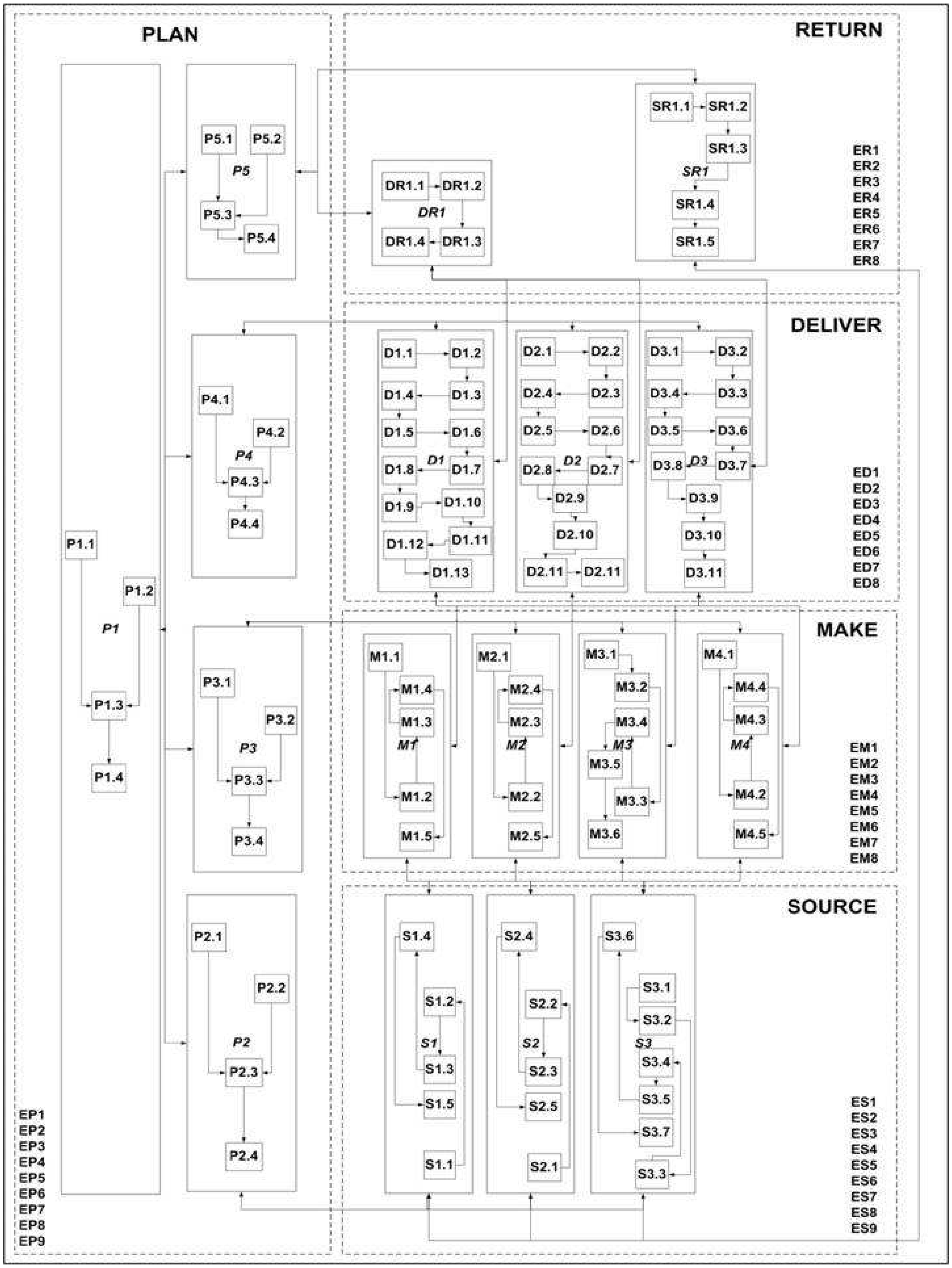

Figure 7.20: Outline of the GISDataSCOR model

Each Level 2 process category and Level 3 process element consists of the following: a description of the process; the five performance attributes (reliability, responsiveness, flexibility, cost and assets) and their related metrics; best practices and related aspects such as Internet access that can be used to run the process optimally; the different inputs needed for proper functioning; and the outputs generated by the process. Table 7.19 gives an example of a GDS Level 2 process category and Table 7.20 shows a GDS Level 3 process element of the MAKE management process.

Table 7.19: Example of a GDS Level 2 process category (Schmitz, 2006)

Process Category: **Make-to-Stock M1**	
Process Category Definition	
The process of manufacturing in a make-to-stock environment adds value to GIS products through the creation of new spatial data and/or value addition of existing spatial data. Make-to-stock products are intended to be shipped from finished goods or 'off the shelf'. They are completed prior to receipt of a customer order, and are generally produced in accordance with a sales forecast.	
Performance Attributes	Metric
Reliability	Warranty costs[1] Performance to customer request date[2]
Responsiveness	GIS product change over time[3] GIS product manufacture time[4]
Flexibility	GIS product change over time[3]
Cost	Value-added employee productivity[5] Indirect to direct headcount ratio[6] Cost per GIS product[7] Overhead cost[8]
Assets	Capacity utilisation[9] Data warehouse[10]
Best Practices	Features
Cellular manufacturing[11]	Manufacturing is broken up into work cells
Organisation to enhance flexibility: Few job classifications, self-directed work force, flat management structure, and cross-functional work teams.	Support for modular skills inventory with links to training databases, compensation systems and operator instructions.
Link individual performance to	

organisational and divisional goals.					
Provide continuous formal training to employees.	Examples are new versions of the GIS software, further tertiary education and project management.				
Lean manufacturing	Use a team-based systematic approach to identify and eliminate wasteful or non-value-adding activities within your manufacturing organisation when creating a GIS product.				
Accurate and approved work instructions/ process plans	Electronic document management that maintains current Standard Operating Procedures (SOPs)				
Inputs	Plan	Source	Make	Deliver	Return
Outputs	Plan	Source	Make	Deliver	Return

Explanatory notes:

[1.] Warranty costs include materials, labour and problem diagnosis of GIS product defects.

[2.] Has the Make-to-Stock GIS product been completed on or before the customer order request date? Results are expressed as a percentage of total requests received.

[3.] How quickly can the GIS unit change from the production of one GIS product to a new GIS product?

[4.] The time it takes to create a GIS product from the production begins when the GIS product is released for delivery in the data warehouse.

[5.] Value added per employee is calculated as total product revenue less total material purchases ÷ total employment (in full-time equivalents).

[6.] Ratio of total number of employees required to support production in general without being related to a specific product, indirect labour, to the total number of employees who are specifically applied to the product being manufactured or used in the performance of the service, direct labour.

[7.] Total cost of manufacturing the GIS product, also known as Cost of Goods Sold (COGS). This cost includes direct costs (labour and materials such as GIS products and data) and indirect costs (overhead).

[8.] Costs incurred in the operation of a business that cannot be directly related to the individual products or services produced. These costs, such as light, electricity, heat, hardware rental, supervision and maintenance, are grouped in several pools and distributed to units of product or service by some standard allocation method such as direct labour hours, direct labour rand (dollars), or direct materials rand (dollars).

[9.] How often is a resource used to produce a GIS product? Resources include hardware and software.

10. The value of the content of the data warehouse.

11. If a GIS product consists of several layers such as in a 1:50 000 topographical map, then the concept of cellular manufacturing can be utilised. Each layer is a 'cell'.

Table 7.20: Example of a GDS Level 3 process element (Schmitz, 2006)

Process Element: **Schedule production activities M1.1**					
Process Element Definition					
The setting up and running of the production of the GIS product. The plan includes resources and sources of spatial data required for the production.					
Performance Attributes	Metric				
Reliability	Schedule achievement[1]				
Responsiveness					
Flexibility					
Cost	Scheduled resource costs[2]				
Assets	Capacity utilisation[3]				
Best Practices	Features				
Cross training/certification.	HR/certification support.				
Schedule optimises use of shared resources.	Detailed maintenance schedule in place. Must fit with production schedules.				
Inputs	Plan	Source	Make	Deliver	Return
Production plans.	P3.4				
Scheduled receipts.		S1.1 S2.1 S3.1			
Information feedback.			M1.2 M1.3 M1.4 M1.5		
Equipment and facilities schedules and plans.			EM.5		
GIS product design/MRP					
Outputs	Plan	Source	Make	Deliver	Return
Production schedule	P3.2	S1.1 S2.1 S3.3		D1.3 D1.8	

Explanatory notes:

1. Was the GIS product created on schedule? Schedule over or under runs (i.e. product completed after or before the scheduled time) should be recorded for future planning purposes.

2. The measure of the cost of people, information systems, management direction, and any other costs associated with provided schedules for the production of the GIS product.

3. A measure of how intensively a resource is being used to produce the GIS product. Some factors that should be considered are internal production capacity, constraining processes, direct labour availability and key spatial data and their related attributes availability.

GDS was developed using a Delphi process whereby knowledgeable persons in GIS were invited to participate with regard to best practices for each of the five management processes and the experience of the researcher in the field of GIS (Schmitz, 2006). GDS is used to analyse the supply chain with the aim of understanding the GIS unit's practices and business rules, for example when sourcing or creating a GIS product. GDS provides some guidelines on best practices and the features of these practices to help the GIS unit to improve the performance of the supply chain (see Tables 7.19 and 7.20). Each process category (Level 2) and process element (Level 3) has the five performance attributes and their related metrics to measure the performance of the supply chain. The aim of the GIS unit is to improve on these metrics by improving the supply chain. Explanatory notes are given for each process category and process element to clarify the different metrics and terminology where necessary. GDS thus guides the GIS unit to areas of excellence and problems areas within the supply chain.

The process of analysing the supply chain at GDS Level 3 of a GIS unit is known as the "*The Staple Yourself to an Order Analysis*", which is a process developed by Shapiro, Rangan and Sviolka in 1992, published in the *Harvard Business Review* on 1 July 1992 (Bolstorff and Rosenbaum, 2003). The objective, according to the authors of the article, is that a person should follow the whole process of creating a product (a GIS product for the purpose of this study) at Level 3, from when an order is placed for the product right through the supply chain to when the product is delivered to the customer (Bolstorff and

Rosenbaum, 2003). To collect the data at Level 3 for ESI-GIS, workbooks have been developed using GDS with space added to record current business practices and rules, possible suggestions to improve the various practices, as well as the process steps involved to execute the process element. Table 7.21 gives an example of a process element from the workbook. Other information that is also entered is possible problems (disconnects) encountered and the performance of the process element, which is entered alongside each of the metrics indicated.

Table 7.21: Example of a process element of the SOURCE workbook

Process Element: **Schedule product deliveries S1.1**		
Process Element Definition		
Scheduling and managing the execution of the individual deliveries of GIS products or data against an existing contract or purchase order. The requirements for GIS products or data releases are determined based on the detailed sourcing plan.		
Line function/Department		
Performance Attributes	Metric	Values
Reliability	% scheduled GIS product or data received within supplier's lead time[1]	0
Responsiveness		
Flexibility		
Cost	Product management and planning costs as a % of product acquisitions costs[2]	6% management cost
Assets		
Current Practices	Improvements	
No definitive sourcing plans in place. Ad hoc	Using a cartographic model to understand GIS process and data requirements that then can be sourced according to a plan.	
	ESI-GIS to collect GIS products physically to ensure that data are received on time (cost implication).	

Core data sets are sourced every 4 months	
	Appoint database administrator to streamline data procurement.
Business Rules	**Improvements**
Corporate procurement rules need to be adhered to. Procurement staff not trained adequately and lack of experience.	Look into the possibility of obtaining dedicated buyers for ESI-GIS. Online procuring of data, etc. using Workflow, etc.

Inputs	Plan	Source	Make	Deliver	Return
Sourcing plans	P2.4				
Source execution data		ES.2			
Logistics selection[3]		ES.6			
Production schedule			M1.1 M2.1 M3.1 M4.1		
Issue signals[4]			M1.2 M2.2 M3.3 M4.2		
Defective GIS products received for correction					DR1.4
List of suppliers		ES.7			
Outputs	**Plan**	**Source**	**Make**	**Deliver**	**Return**
Procurement signal (supplier)[5]					
Sourced product on order	P2.2	ES.9			
Scheduled receipts			M1.1 M2.1 M3.1 M4.1		

Disconnects
Suppliers not delivering on time, which delays the project delivery time.

Process steps:

- Core data sets, a contract is in place with suppliers to deliver updated data sets every 4 months.

Comment: delivery by suppliers of core data sets still not on time but does not adversely affect project delivery.

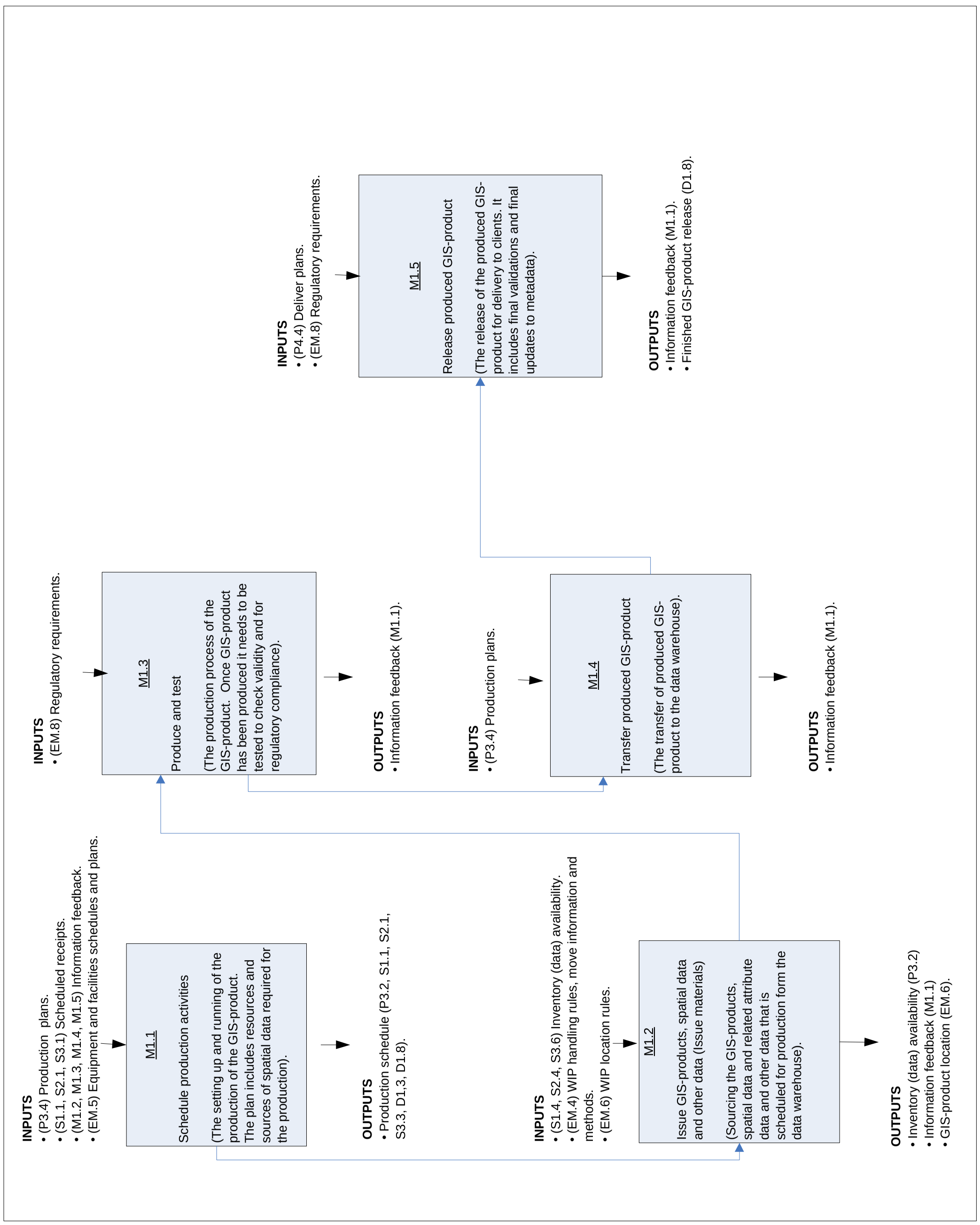

Figure 7.21: The different process elements (GDS Level 3) of each process category (GDS Level 2)

(from Schmitz, 2006:106)

The inputs and outputs listed in GDS and the workbooks indicate which process elements provide inputs into the applicable process elements to enable them to function. The output is the information that is sent to the other process elements to enable them to function.

Figure 7.21 above gives an example of connected process elements with their various inputs and outputs to make a stocked product. Once the supply chain has been analysed the various flows of information and materials between each process element can be mapped.

Each management process has its **ENABLE** processes which collects, prepares, stores, maintains and manages information or relationships on the different planning and execution processes as defined in the process categories (Level 2) and process elements (Level 3) (Supply-Chain Council, 2005). Table 7.22 gives an example of the ENABLE process for the MAKE management process which maintains and manages capital equipment such as software, hardware and peripherals, e.g. plotters and printers that are required to create a GIS product (Schmitz, 2006).

Table 7.22: Example of an ENABLE process for the MAKE management process

Enable Process: **Manage MAKE equipment and facilities EM.5**	
Enable Process Definition	
The process of specifying, maintaining and dispositioning MAKE's capital assets to operate the supply chain production processes. This includes repair, alteration, calibration and other miscellaneous items to maintain production capabilities.	
Performance Attributes	Metric
Reliability	Unplanned maintenance downtime % of total production time[1] Mean time between failure[2]
Responsiveness	
Flexibility	Mean time to repair or replace asset[3]
Cost	Equipment/facility maintenance cost as % of manufacturing controllable cost

Assets	Actual asset life maintenance cost as % of replacement value[4]				
Best Practices	**Features**				
Total Preventative Maintenance Programme[5]	Schedule indicating maintenance programme for the current financial year.				
Changeover reduction Continuous Improvement Programme[6]	Changeover process flow element identification, instructional directions to conduct changeover, and measurement tool, which can be used to prioritise and track results of improvement efforts.				
Facility & Equipment Environmental / Safety Audit System					
Inputs	**Plan**	**Source**	**Make**	**Deliver**	**Return**
Production plans and budgets.	P				
Production quality and policies.			EM.2		
Equipment and facilities monitoring information.					
Manufacture's recommended maintenance schedules and specifications.					
Outputs	**Plan**	**Source**	**Make**	**Deliver**	**Return**
Preventative maintenance schedule.	P	S	M1.1 M2.1 M3.2 M4.1		
Equipment and facilities schedules and plans.			M1.1 M2.1 M3.2 M4.1		
Equipment and facilities replacement and disposition plans.	P		EM.6		
Parts and services consumed.		S			
Equipment and facilities maintenance history.		S	M		
Production status.			EM.7		

Explanatory notes:

1. Per cent of time that facilities or equipment are unavailable when scheduled compared to the total production time of the GIS product at GIS unit (unscheduled unavailability impacts on the planned lead time for specific GIS products).

2. The average time interval between failures for repairable equipment and facilities (e.g. plotters and printers) for a

defined unit of measure (e.g. operational hours). [3.] The average time to repair equipment and facilities for a defined unit of measure (e.g. operational hours). [4.] Measure of total life cycle maintenance cost of an asset compared to its replacement cost. This ratio is based on maintenance cost to date so that the replacement or upgrade cost can be evaluated as the asset ages on an on-going basis. [5.] Looks at the regular maintenance of plotters, printers and other hardware in a GIS unit. [6.] Looks at the periodic upgrades of software and hardware. Changeovers must be done with the least possible disruption to production processes of GIS products.

This section discussed the GDS model that was used in the second study to analyse the supply chains of and the use of supply chain management in ESI-GIS, which will be discussed in the next section.

7.5 The use of supply chain management and GISDataSCOR at ESI-GIS: the 2006/7 study

This section discusses the second study which was conducted between October 2006 and May 2007. The same methodology was used as for the first study as discussed in Section 7.3. The main difference between this study and the first is that in this study the complete analysis was done as suggested in the methodology section, which included the analysis of the supply chain at GISDataSCOR (GDS) Level 3. The business context of ESI-GIS, as with the first study, is discussed in Chapter 6.

This discussion starts, as in Section 7.3, with the supply chain definition matrix for the 2006/7 study, followed by the performance and benchmarking phase of the methodology. When the first study was done (Section 7.3), ESI-GIS's spatial data and spatial modelling GIS product range were two separate entities. Subsequently ESI-GIS combined these two GIS product ranges into one owing to overlaps in the production (de la Rey, 2006). This was used as the basis to analyse the supply chain, since it is the major business of ESI-GIS. ESI-GIS also expanded its customer market to include private organisations and ad hoc projects. Ad hoc project customers cross-cut across the three other customer channels, but owing to its short project life span (4 days) and the number of these ad hoc projects (120 of them in this study), it was decided to regard them as a customer channel on their own. Ad hoc projects are stocked GIS products projects, where ESI-GIS stocks available GIS products and the GIS product is selected, compiled and delivered to the customer. Services are rendered by ESI-GIS to customers who need assistance with the GIS products and standards. Automated mapping and facilities management standards are discussed in Section 7.3. Table 7.23 gives the supply chain definition matrix for this study. As in Section 7.3, the supply chain analysis encompassed all the different GIS product ranges.

Table 7.23: Supply chain definition matrix for the 2006/7 study

SC definition matrix	**Geography of customers/market channel**			
Product/Customers	Parastatals	Public Organisations	Private Organisations	Ad hoc projects
Services	X	X		X
Spatial data and modelling	X	X	X	X
Post-Fire Analysis	X			
Standards for AM/FM	X	X		

7.5.1 Performance and benchmarking

This section discusses the performance and the benchmarking of ESI-GIS. The same procedure as for the first study was followed. The SCORcard was initially captured in October 2006, using actual and confirmed financial information as on 31 July 2006. The SCORcard was subsequently updated with year-end audited financial results to provide a full financial year's supply chain performance. Table 7.24 gives the SCORcard as at the end of the 2006/7 financial year ending on 31 March 2007. The 2004/5 scores are given in brackets where available.

Table 7.24: The SCORcard for ESI-GIS spatial data and modelling GIS products (2006/7 study)

	Performance Attribute / Category	Level 1 Performance Metric	Actual	Parity (P)	Advantage (A)	Superior (S)	Parity Gap (Actual – Parity)	Requirements Gap (Actual – P or A or S)	Opportunities
Customer facing	Supply Chain Delivery Reliability	Delivery Performance	**73% (77%)**	**P**					
		Perfect Order Fulfilment	**68% (43%)**		**A**				
	Supply Chain Responsiveness	Order Fulfilment Lead Time (days)	**120** (measured differently for this study)	**P**					
	Supply Chain Flexibility	Supply Chain Response Time (days)	**43 (n/a)** (for ad hoc projects it is 3 days)		**A**				
Internal facing	Supply Chain Costs	Costs of Goods (Costs of goods sold – COGS)	R14 565 414.48/ R16 658 506.46 = **87% (50%)** (labour costs = R1 497 645.41)			**S**			10% reduction in labour costs due to improved data and a further 3% reduction in labour cost through skills improvement
		Total Supply Chain Management Costs	R1 743 072.20/ R16 658 506.46 = **11% (26%)**		**A**				
		Sales, General and Administration Costs (SG&A Costs)	R350 019.78/ R16 658 506.46 = **2% (24%)**		**A**				
		Returns Processing Costs	Not measured as a separate entity, part of COGS						
	Supply Chain Asset Management Efficiency	Cash-to-Cash Cycle Time (days)	**1 516 (n/a)** (Assumption 1)						
			161 (n/a) (Assumption 2)						
		Inventory Days of Supply (days)	**1389 (n/a)** (Assumption 1)						
			34 (n/a) (Assumption 2)						
		Asset turns	**9.89 (n/a)**						
S	Profitability	Gross Margin	**-17.88% (50%)**		**A**				

	Performance Attribute / Category	Level 1 Performance Metric	Actual	Parity (P)	Advantage (A)	Superior (S)	Parity Gap (Actual – Parity)	Requirements Gap (Actual – P or A or S)	Opportunities
		Operating Income (Margin)	**-31.98% (23%)**	**P**					
		Net Income (Net Operating Income)	Taxes not available						
	Effectiveness of Return	Return on Assets	Not available						

As the Parity, Advantage and Superior ratings are subjective, based on ESI-GIS's manager's own experience of his interaction with other GIS units, it was not possible to calculate the parity and requirements gap for each rating. The delivery performance was slightly lower than in the 2004/5 study, but owing to the implementation of the various improvement implementations as discussed in Section 7.3.4, ESI-GIS's perfect order fulfilment improved significantly from 43% to 68%. The high cost of goods is due to the large amount of money that was spent by ESI-GIS on spatial and related non-spatial data from their suppliers. The amount spent was R13 067 769.07.

With regard to Cash-to-Cash cycle time, it was decided to make the following assumptions for calculating its value: the first assumption (Assumption 1) is that the data, which is estimated at R60 000 000.00 (de la Rey, 2007), is only used once, therefore the Cash-to-Cash cycle time that measures the number of days that cash is tied up as working capital (Supply-Chain Council, 2001) is 1 516 days. Most GIS units re-use the data regularly. The average re-use of the data by ESI-GIS is 41 times (de la Rey, 2007), thus the data become "cheaper" the more it is used. This is Assumption 2. Using Assumption 2, the value of the data is R60 000 000.00 divided by 41, which equals R1 463 414.63, and this gives a Cash-to-Cash cycle time of 161 days. The same assumptions were used to calculate the inventory days of supply as reflected in Table 7.24.

Asset turn, according to Bolstorff and Rosenbaum (2003: 52), *"is calculated by dividing revenue by total assets including working capital and fixed assets"*. This be can roughly translated for every rand spent; the GIS unit gets an x amount of rand back through revenue. ESI-GIS's asset turn is 9.89, which indicates that for every R1.00 that ESI-GIS spends, it makes R9.89. The negative gross and operating margin was due to non-payment of R4 300 099.57 by customers at the end of the financial year. This section gives an overview of ESI-GIS's supply chain performance, which has improved since the first study in March 2005. The next step is to determine ESI-GIS's material flow at GDS Level 2 process category level.

7.5.2 AS IS material flow and SCOR Level 2 processes

Chapter 6 and Section 7.5.1 gave an overview of ESI-GIS as a business unit and how it performs. To develop an understanding of ESI-GIS's supply chain with the aim of improving its performance, it necessary to unpack the supply chain using SCOR Level 2 process categories to map the current supply chain. This section discusses ESI-GIS's AS IS material flow and the SCOR Level 2 process map for all the GIS products created by ESI-GIS. This exercise was done to give an overview of ESI-GIS's supply chain, which is used as an aid for a disconnect analysis. The disconnect analysis is a process that is used to identify problems in the supply chain as discussed in Section 7.2.3.

Figures 7.22 and 7.23 show the flow of material from suppliers situated across South Africa as well as the flow of GIS products to the clients.

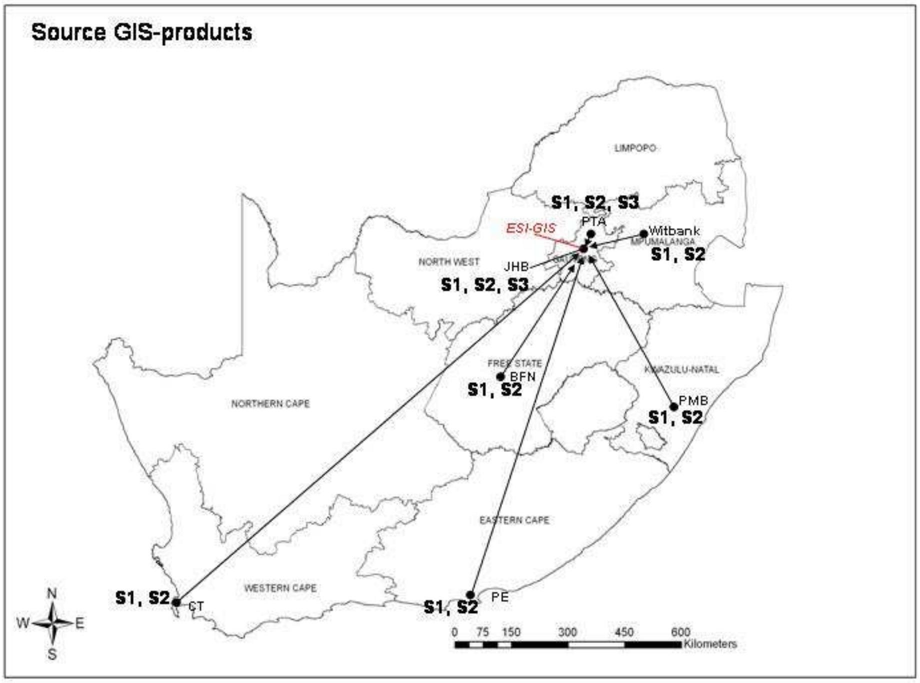

Figure 7.22: Sourcing proprietary data sets

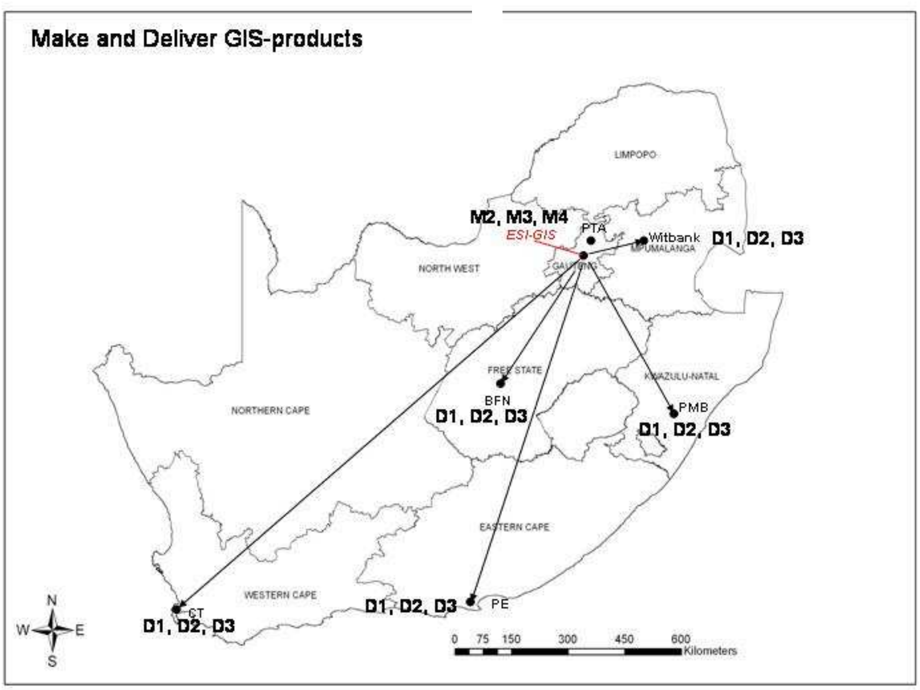

Figure 7.23: MAKE and DELIVER processes

Using information obtained from the material flow maps, the GDS Level 2 AS IS material flow diagrams are drawn. These are discussed in the next section.

7.5.3 Mapping the processes and doing the disconnect analysis

Figure 7.24 gives the processes involved in the production of GIS products by ESI-GIS. Using the Spatial Data and Modelling product range as an example, the data are sourced from nine different sources, including data from Eskom's regional offices, to manufacture four GIS products in the Spatial Data and Modelling range. The GDS Level 2 material flow diagram is the same as in the first study, which is discussed in Section 7.2.3. These four GIS products are:

- Seven spatial data sets that are updated every four months for Eskom Distribution.
- Large-scale aerial photography for detailed electrification design.
- GIS products for supporting electrification planning.
- Electrification planning models.

The sourced data are stored in a data warehouse from where the data are then sourced for producing the products. Currently "data warehouse" is a loose term used by ESI-GIS since the sourced data sets are currently stored on various removable hard disks, CD-ROM and DVD. ESI-GIS is in the process of establishing a proper data warehouse. The completed GIS product is then stored in the data warehouse and accessed when the customer needs it.

Once the GDS Level 2 processes had been mapped, a disconnect analysis was done together with the staff from ESI-GIS using the same format as in the first study. The aim of supply chain management is to create a supply chain that is efficient and effective. To make a supply chain efficient and effective, the supply chain must be analysed using the GDS model and problems within the supply chain must be identified.

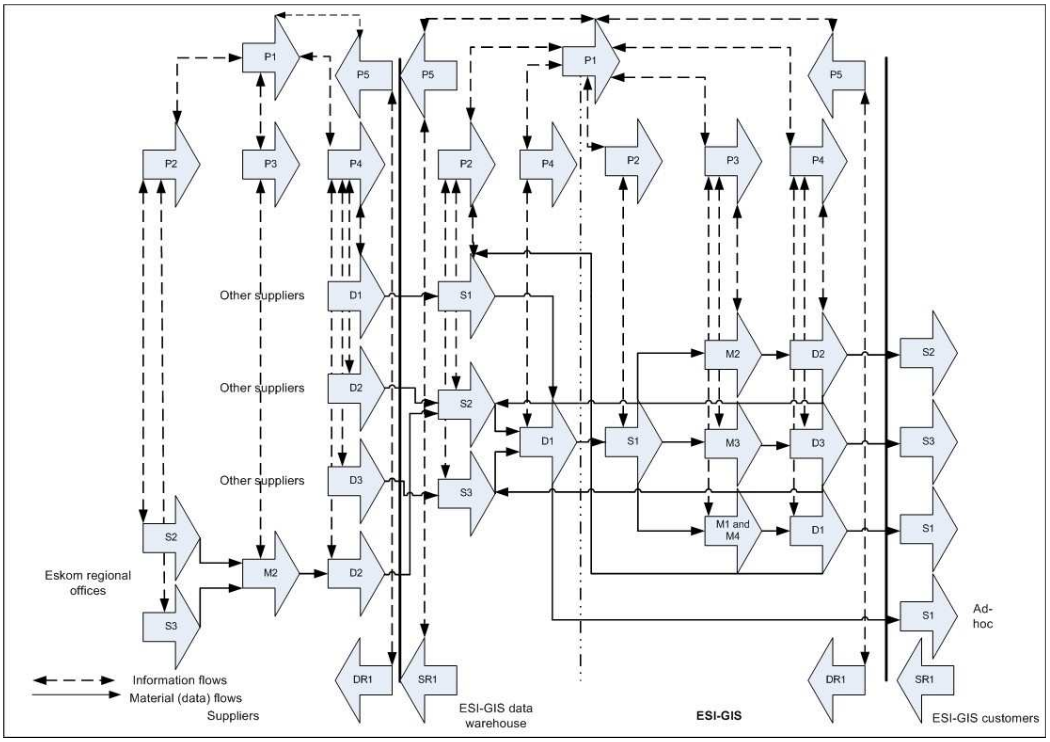

Figure 7.22: ESI-GIS GDS Level 2 processes

By addressing the identified problems, the efficiency and effectiveness of the supply chain is improved. The process of conducting the disconnect analysis has been discussed in Section 7.2.3. The disconnect analysis was conducted on the 10 October 2006 and the following staff members participated in the disconnect analysis:

- Adri de la Rey (Manager)
- Ansunette van der Walt (Senior Advisor GIS)
- S'lindi Mhlongo (Officer Information Technology)
- Mmbengeni Makungo (Officer Information Technology)
- Dumisani Sibande (Officer Information Technology)
- Siyangiso Sibindi (Officer Information Technology).

Table 7.25 gives the results of the disconnect analysis.

Table 7.25: Disconnect analysis results for the 2006/7 study

GDS element	ID
PLAN	**1**
Project planning problems	**1.1**
Understanding customer requirements	***1.1.1***
Customers themselves do not know exactly what they want	1.1.1.1
Project planner does not know exactly what the customer wants	1.1.1.2
Corporate financial process	***1.1.2***
Procurement delays impact on planning of projects	1.1.2.1
Eskom financial processes not clearly understood	1.1.2.2
Eskom financial processes are insufficient to support funding of specific projects	1.1.2.3
Eskom financial processes impact on the delivery of completed GIS products	1.1.2.4
Supply chain flexibility	***1.1.3***
Ad hoc requests impact on delivery of longer-term projects	1.1.3.1
Lack of planning by customer which leads to ad hoc requests	1.1.3.2
Time	***1.1.4***
Too much paperwork which leads to cumbersome planning of projects	1.1.4.1
Not enough time spent on the actual planning process	1.1.4.2
Lack of understanding of the scope of the project which leads to wrong project time span planning	1.1.4.3
Regulatory requirements	**1.2**
ISO processes not updated	1.2.1
ISO meetings are not being held any more	1.2.2
Resources	**1.3**
Not enough personnel resources to do tasks, including ad hoc tasks	1.3.1
Data resources not planned thoroughly	1.3.2
Data availability	**1.4**
Lack of database management skills	1.4.1
Do not know what data are available	***1.4.2***
Duplication of data	1.4.2.1
Metadata not centralised	1.4.2.2
Customer not included in the planning process	**1.5**
No communication with the customer	1.5.1
Inability to provide progress reports to customers	1.5.2
SOURCE	**2**

GDS element	ID
Faulty data	**2.1**
Missing metadata	2.1.1
Wrong data formats	2.1.2
Non-compliance with data standards	2.1.3
Wrong projections	2.1.4
Data quality problems	2.1.5
Outdated data	2.1.6
Wrong data	2.1.7
Procurement	**2.2**
Eskom corporate financial processes	2.2.1
Unwillingness to share data	2.2.2
Time it takes to receive the data	2.2.3
Transporting the data from suppliers to ESI-GIS	2.2.4
MAKE	**3**
Inadequate resources	**3.1**
Hardware	***3.1.1***
Slow PCs	3.1.1.1
Network problems	3.1.1.2
Software	***3.1.2***
Limited software availability due to licence restrictions	3.1.2.1
Software version problems	3.1.2.2
Personnel	***3.1.3***
Lack of advanced GIS skills	3.1.3.1
Wrong personnel do wrong work on project	3.1.3.2
Not enough personnel	3.1.3.3
Project execution problems	**3.2**
Interruptions caused by sudden reallocation of personnel to work on another project	3.2.1
Not adhering to standard operating procedures (SOPs)	3.2.2
Process not documented as required	3.2.3
Poor data management during project execution	3.2.4
No accountability taken for the data	3.2.5
Inadequate time allocation to execute project	3.2.6
Unnecessary pre-processing of data due to correcting faulty data	3.2.7
Inadequate quality control measures	3.2.8

GDS element	ID
DELIVER	**4**
Inadequate delivery mechanisms	**4.1**
No map server available	4.1.1
Existing data server not always available	4.1.2
Data size restricted to 2 MB only	4.1.3
LAN availability is problematic	4.1.4
CD-ROMS too small for certain data sets	4.1.5
Courier service	**4.2**
Reliable but high costs involved	4.2.1
Not always on time with delivery	4.2.2
Customer problems	**4.3**
Lack of skills on customer's side to use delivered data	4.3.1
Customers unwilling to sign off delivered data due to lack of understanding of their own data needs	4.3.2
Lack of necessary skills/procedures to successfully sign off the delivered data	4.3.3
Version control	**4.4**
Customers do not keep track of changes in data delivered to them	4.4.1
ESI-GIS sends wrong version to customers	4.4.2
RETURN	**5**
Faulty data from suppliers	**5.1**
Wrong projections, datums and formats	5.1.1
Extra costs involved for ESI-GIS to get corrected data from suppliers (either in sending the data back or paying supplier to correct data or both)	5.1.2
Data currency is questionable	5.1.3
Faulty data from ESI-GIS	**5.2**
Quality control not enforced properly which leads to poor data delivered	5.2.1
Data delivered with wrong projections, datums and formats	5.2.2
OTHER	
ESI-GIS is forced to deliver data to outside contractors contracted by other sections in Eskom	

As with the first study in Section 7.3.2, the above were then regrouped into five unique problem statements, which are reflected in Table 7.26.

Table 7.26: Unique problem statements for the 2006/7 study

Problem statement	% improvement	New ID	Old IDs
Inadequate project planning	-	1	1.1 (excluding 1.1.2), 1.3.2, 1.4, 1.5 and 3.1.3.2
Poor data	10	2	2.1, 5.1, 5.2, 1.2
Production problems	3	3	3.1, 3.2, 1.3.1 and 1.2
Problems with the delivery of GIS products	-	4	4.1, 4.2, 4.3 and 4.4
Procurement problems	-	5	1.1.2 and 2.2

The information from Tables 7.25 and 7.26 is combined to create the following five cause-and-effect diagrams for each problem statement. Figure 7.25 gives the cause-and-effect diagram for inadequate project planning. This problem statement is an expanded version of the "Unclear project requirements" problem statement of the 2004/5 study. The reason for having identified a high number of reasons is that staff members attended a course on project management, which was an outcome of the 2004/5 study, and were thus more attentive to possible project planning and management problems as reflected in the tables above and the cause-and-effect diagram in Figure 7.25.

Figure 7.26 gives the cause-and-effect diagram for the "Poor data" problem statement, which is virtually the same as the "Poor data" problem statement in Figure 7.12. Although ESI-GIS improved their supplier relationships, ESI-GIS was still experiencing problems with the data received from suppliers. An interesting aspect under "Faulty data from suppliers" is the fact that ESI-GIS are currently carrying the costs to correct faulty data from suppliers.

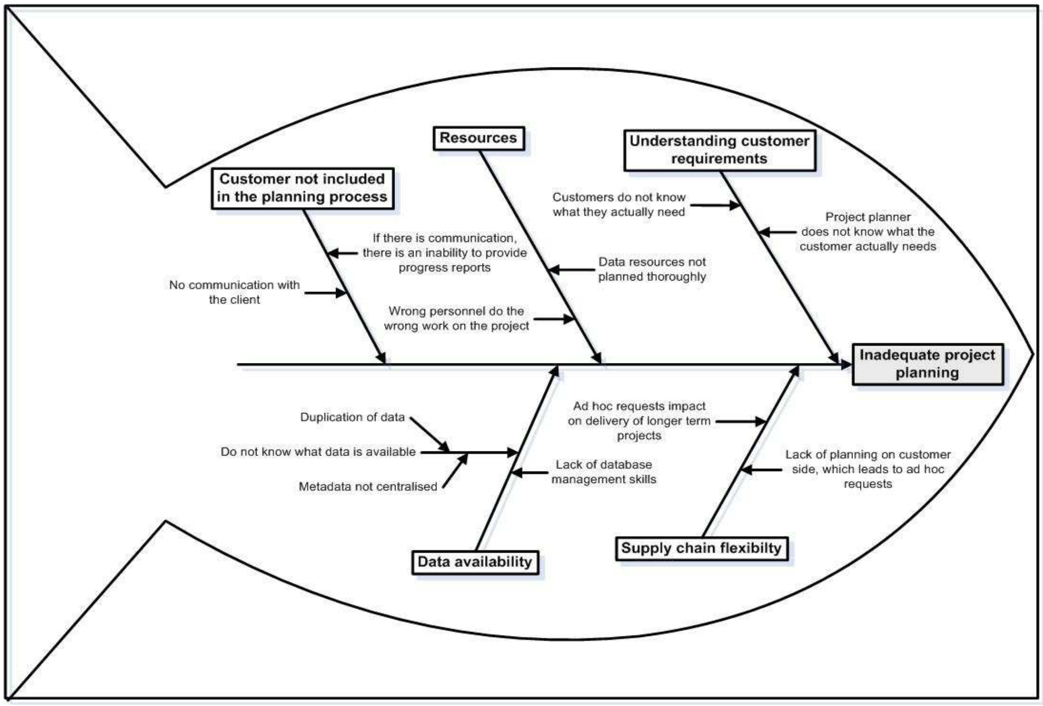

Figure 7.25: Inadequate project planning

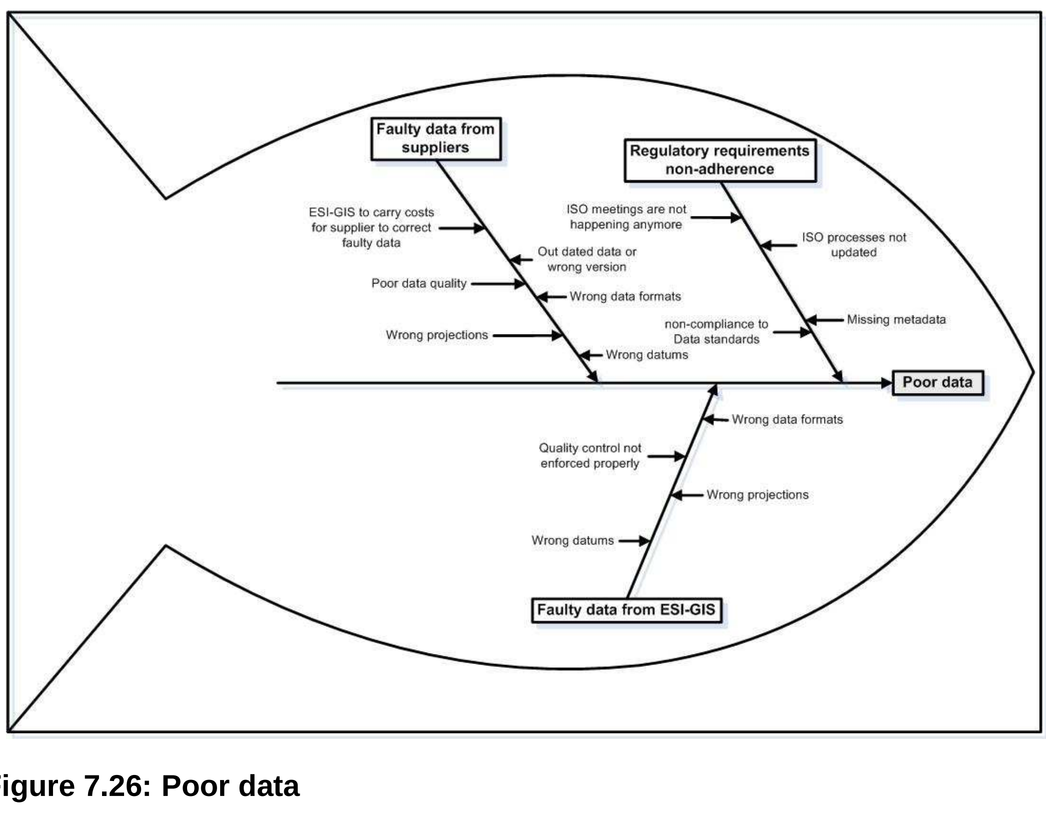

Figure 7.26: Poor data

From further enquiries into this aspect, it transpired that in most cases ESI-GIS has to prove to the supplier that the data are faulty, and thus incurs labour costs for providing proof (de la Rey 2007). The "Faulty data from ESI-GIS" cause can be improved by addressing the "Production problems" problem statement, which is shown in Figure 7.27.

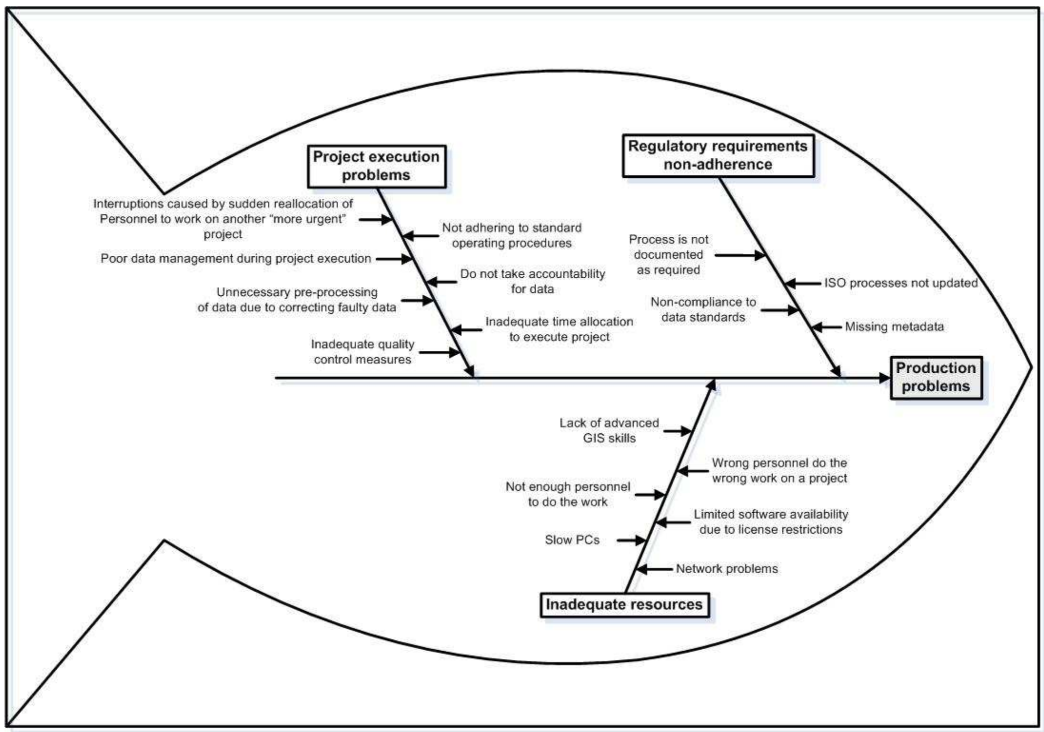

Figure 7.27: Production problems

In the "Production problems" problem statement the cause "Inadequate resources" has similar problems to those identified in the "Inadequate skills to perform certain tasks" problem statement of the 2004/5 study as shown in Figure 7.14.

The "Poor 'transport'" problem statement with regard to downloading and uploading of data and the "Poor process performance" problem statement indicate slow personal computer processing times (Figure 7.16). The two new causes that were identified in this study are "Project execution problems" and "Regulatory requirements non-adherence". The latter was identified in the "Poor data” problem statements of both studies, but only in this study with regard to the production of the GIS products.

Although delivery problems were listed as a cause in the “Poor ‘Transport’” problem statement in the 2004/5 study, it was identified as a separate problem statement in the 2006/7 study with several causes identified. Network problems were cited again as one of the causes of the delivery problem, which is outside ESI-GIS’s control as mentioned in the 2004/5 study. Another cause that was identified again in this study is the “lack of skills on customer’s side to use delivered data” (see Figure 7.28), which was identified in 2004/5 as a cause of the “Inadequate skills to perform certain tasks” problem statement. As mentioned in Section 7.3.4, ESI-GIS plans to implement training sessions for GIS product users at the regional offices to enable them to use GIS products effectively.

The last problem statement of the 2006/7 study is “Procurement problems” as shown in Figure 7.29. Two sub-causes were identified. The first was “Corporate financial process”, which according to the staff members is a source of frustration since ESI-GIS cannot influence the procurement policy of Eskom. The only influence ESI-GIS can have on the procurement process is to appoint a dedicated procurement staff member who can be trained in the specific procurement needs of ESI-GIS. Unfortunately, there is a high staff turnover at the procurement section, thus making any efforts to train a person to assist with ESI-GIS’s specific procurement needs ineffective (de la Rey, 2006). The second sub-cause, “Unwillingness to share data”, is similar to the sub-cause identified in the “Poor data” problem statement under “Poor data delivery from suppliers” cause in the 2004/5 study. A new sub-cause identified in this study is the long lead times of the suppliers to deliver data to ESI-GIS.

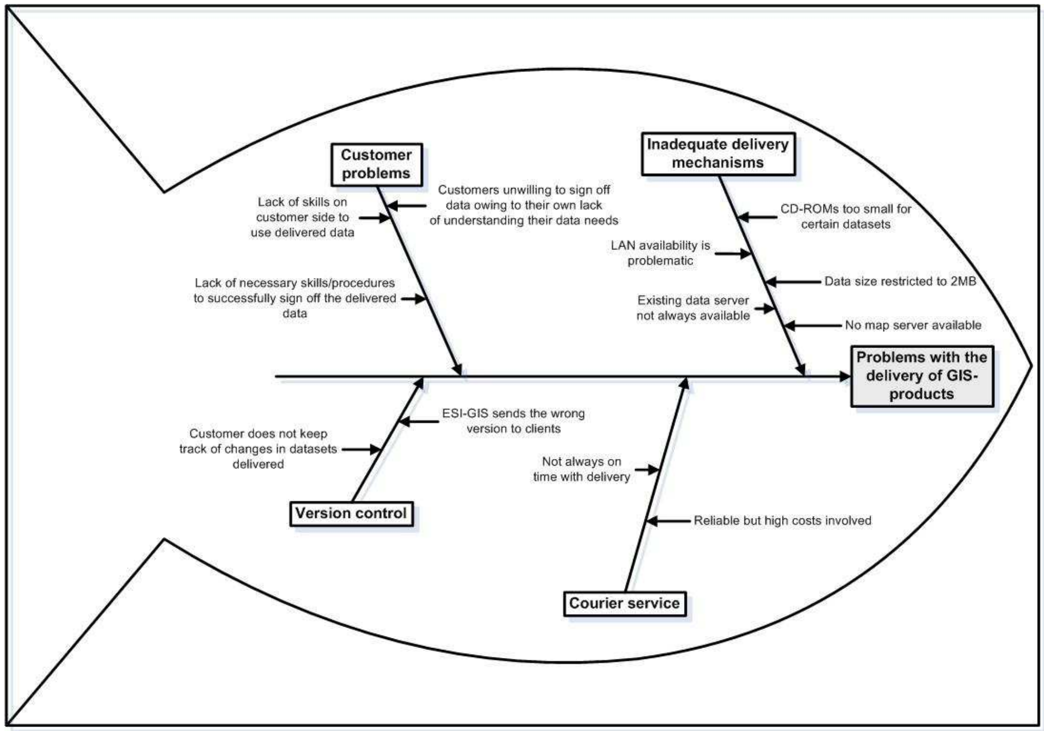

Figure 7.28: Problems with the delivery of GIS products

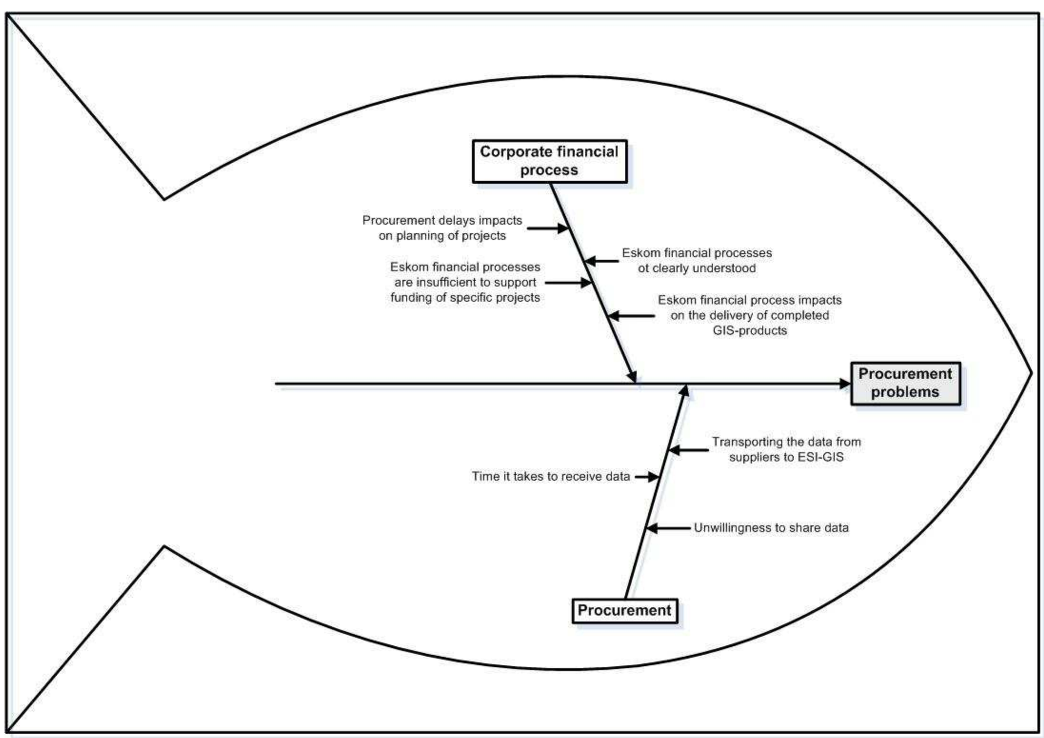

Figure 7.29: Procurement problems

As with the previous study, each problem statement is converted into possible opportunities using the opportunity spreadsheets as discussed in Sections 7.2.4 and 7.3.2.3. The opportunity spreadsheets are given in Appendix C. In this study, it was decided to concentrate mainly on the following two problem statements:

- Poor data
- Production problems.

Although the other problem statements do affect the efficiency and effectiveness of ESI-GIS, it was concluded that if the above two problem statements were addressed significantly, it would lead to spin-offs for the other problem statements, except “Procurement problems”.

The following opportunities were identified: if the “Poor data” problem statement were addressed sufficiently it could cause a 10% reduction in labour costs due to fewer man hours spent on rectifying faulty data received from suppliers. If “Production problems” were significantly solved by continuous training of staff to improve their skills base, as well as adherence to standards set by ESI-GIS and better production planning, the savings in labour costs are conservatively estimated at 3%. Table 7.27 gives the savings in monetary value based on the above opportunities.

Table 7.27: Opportunities identified for the 2006/7 study

Problem statement	Opportunity	Cost savings
Poor data	Reduction of 10% in labour costs based on improving the quality of data	R149 764.54
Production problems	Reduction of 3% in labour costs by improvement of resources, planning and adherence to standards	R44 929.36
Problems with the delivery of GIS products	None identified	R0.00

Inadequate project planning	None identified	R0.00
Procurement problems	None identified	R0.00
Poor process performance	None identified	R0.00
	Total savings	**R194 693.90**

The total savings would be R194 693.90, which de la Rey (2007) indicated would allow ESI-GIS to employ an additional GIS staff member, which in turn would to some extent address the “Inadequate resources” cause of the “Production problems” problem statement. An example of an opportunity spreadsheet is given in Figure 7.17. According to the methodology, an opportunity priority matrix should be developed, but it was decided not to prioritise the two selected problem statements, since both were regarded as equally important to improve the supply chain. The opportunity spreadsheet from which the above values were obtained is on the accompanying CD (PhD/GDS Spreadsheets).

In conclusion, the cause-and-effect diagrams give a comprehensive overview of the different causes and sub-causes (problems) of the five problem statements, but do not indicate where in the supply chain these problems occur. The above analysis only indicated the location of the problem at management process level (GDS Level 1). It is necessary to identify at which process category (GDS Level 3) the problem occurs. This information can then be used to address the problem. The next section discusses the process followed to link the causes of the problems to Level 3 process elements.

7.5.4 Improving the supply chain of ESI-GIS

This section looks at the AS IS (the current supply chain) and the TO BE (the future supply chain) processes to address the problems identified in the previous sections using the methodology as discussed in Section 7.2.5. This section starts with mapping the areas of improvement using the GISDataSCOR (GDS) Level 2 process categories. This is used as a guide for the GDS Level 3 process element mapping of the supply chain. The GDS Level 3 is used to map the supply chain as it currently is. The information gathered during this process will then be used to improve the supply chain by mapping the future supply chain using GDS Level 3 process elements.

7.5.4.1 Mapping areas of improvement

As mentioned in Section 7.2.5 above, the first step to improve the supply chain is to indicate where at GDS Level 2 AS IS in the material flow diagram these problem statements occur at the different process categories as shown in Figure 7.30.

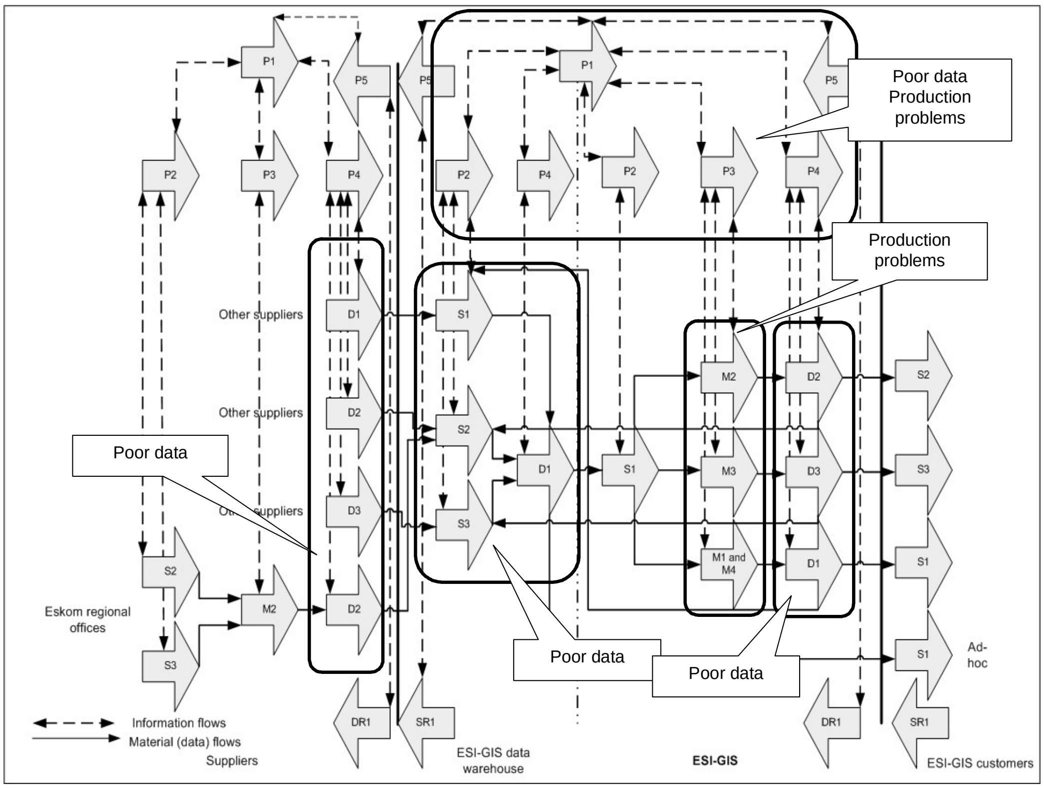

Figure 7.30: ESI-GIS areas of improvements at GDS Level 2

The “Poor data” and “Production problems” are linked to the PLAN (P1 to P5) part of the supply chain, since the supply chain is planned at that specific level and the planning activities have to take into account the improvements envisaged by ESI-GIS. The “Poor data” problem statement is linked to the delivery from suppliers to ESI-GIS and from ESI-GIS to the customers. The “Poor data” problem statement links to the ESI-GIS data warehouse, which at present consists of a collection of stored data on various removable hard disks, DVDs and CD-ROMs. If the data are not catalogued properly, duplication of data may occur if the data are not found. It also indicates that ESI-GIS needs to verify the data during sourcing, which if not done affects the data warehouse's delivery of data for production. The "Production problems" problem statement is linked to different MAKE process categories (M1 to M4), where the GIS products are manufactured by ESI-GIS. Based on this data the supply chain can be improved using the methodology discussed in Section 7.2.5.2 using GDS Level 3 process elements to model the supply chain.

7.5.4.2 Analysing and mapping the AS IS supply chain at GDS Level 3

To improve the supply chain of ESI-GIS, the AS IS supply chain needs to be mapped using GISDataSCOR (GDS) Level 3 process elements and link the information and commodity flows with each process element. Once the mapping is done, each element is analysed using the different workbooks that were developed for each management process as discussed in Sections 7.4 and 7.2.5.2. The mapping is done using SWIM diagrams. Each lane depicts a function of ESI-GIS, namely management, customers, data management and dissemination, centre of expertise and suppliers. Figure 7.31 gives the GDS Level 3 supply chain for ESI-GIS. The dotted lines indicate flows of information and money and the solid black lines indicate the movement of data as well as GIS products. The applicable process elements are placed within the appropriate swimming lane. Table 7.28 gives a description of each process element symbol (ID).

Table 7.28: GDS process categories and process elements

ID	Description	ID	Description
P1	**Plan the supply chain**	**P2**	**Plan SOURCE**
P1.1	Identify, prioritise and aggregate supply-chain requirements	P2.1	Identify, prioritise and aggregate product requirements
P1.2	Identify, prioritise and aggregate supply-chain resources	P2.2	Identify, prioritise and aggregate product resources
P1.3	Balance supply-chain requirements with supply-chain resources	P2.3	Balance product requirements with product resources
P1.4	Establish and communicate supply chain plans	P2.4	Establishing and communicating sourcing plans
P3	**Plan MAKE**	**P4**	**Plan DELIVER**

P3.1	Identify, prioritise and aggregate production requirements	P4.1	Identify, prioritise and aggregate delivery requirements
P3.2	Identify, prioritise and aggregate production resources	P4.2	Identify, prioritise and aggregate delivery resources
P3.3	Balance production requirements with production resources	P4.3	Balance delivery requirements with delivery resources
P3.4	Establish and communicate production plans	P4.4	Establish and communicate delivery plans
P5	**Plan RETURN**	**S1**	**Source Stocked Product**
P5.1	Identify, prioritise and aggregate Return requirements	S1.1	Schedule product deliveries
P5.2	Identify, prioritise and aggregate Return resources	S1.2	Receive product
P5.3	Balance Return requirements with Return resources	S1.3	Verify product
P5.4	Establish and communicate Return plans	S1.4	Transfer product
S2	**Source Make-to-Order product**	S1.5	Authorise supplier payment
S2.1	Schedule product deliveries	**S3**	**Source Engineer-to-Order product**
S2.2	Receive product	S3.1	Identify source of supply
S2.3	Verify product	S3.2	Select final supplier(s) and negotiate
S2.4	Transfer product	S3.3	Schedule product deliveries
S2.5	Authorise supplier payment	S3.4	Receive product
M1	**Make-to-Stock**	S3.5	Verify product
M1.1	Schedule production activities	S3.6	Transfer product
M1.2	Issue material	S3.6	Authorise supplier payment
M1.3	Produce and test	**M2**	**Make-to-Order**
M1.4	Transfer produced GIS product	M2.1	Schedule production activities
M1.5	Release produced GIS product	M2.2	Issue material
M3	**Engineer-to-Order**	M2.3	Produce and test
M3.1	Finalise production	M2.4	Transfer produced GIS product
M3.2	Schedule production activities	M2.5	Release produced GIS product
M3.3	Issue material	**M4**	**Maintain-to-Stock**
M3.4	Produce and test	M4.1	Schedule maintenance activities
M3.5	Transfer produced GIS product	M4.2	Issue material
M3.6	Release produced GIS product	M4.3	Produce and test
D1	**Deliver Stocked Product**	M4.4	Transfer maintained GIS product

D1.1	Process inquiry and quote	M4.5	Release maintained GIS product
D1.2	Receive, enter and validate order	**D2**	**Deliver Make-to-Order product**
D1.3	Reserve GIS product and determine delivery date	D2.1	Process inquiry and quote
D1.4	Consolidate orders	D2.2	Receive, enter and validate order
D1.5	Select shipment mode	D2.3	Reserve resources and determine delivery date
D1.6	Route shipments	D2.4	Consolidate orders
D1.7	Select carriers	D2.5	Select shipment mode
D1.8	Receive product at data warehouse	D2.6	Route shipments
D1.9	Select GIS product	D2.7	Select carriers
D1.10	Generate shipment documentation, verify credit and ship GIS product	D2.8	Receive product at data warehouse
D1.11	Receive and verify GIS product at customer site	D2.9	Generate shipment documentation, verify credit and ship GIS product
D1.12	Install GIS product (if required)	D2.10	Receive and verify GIS product at customer site
D1.13	Invoice and receive payment	D2.11	Install GIS product (if required)
D3	**Deliver Engineer-to-Order product**	D2.12	Invoice and receive payment
D3.1	Obtain and respond to Request for Proposal (RFP) or Request for Quote (RFQ)	**SR1**	**Source return defective product**
D3.2	Negotiate and receive contract	SR1.1	Identify defective product
D3.3	Enter order, commit resources and launch programme	SR1.2	Disposition of defective product
D3.4	Schedule installation	SR1.3	Request defective return authority (if required)
D3.5	Select shipment mode	SR1.4	Schedule defective shipment (if required)
D3.6	Route shipments and select carriers	SR1.5	Return defective product (if required)
D3.7	Receive product at data warehouse	**DR1**	**Deliver Return Defective Product**
D3.8	Generate shipment documentation, verify credit and ship GIS product	DR1.1	Authorise defective product return
D3.9	Receive and verify GIS product at customer site	DR1.2	Schedule defective return receipt
D3.10	Install GIS product (if required)	DR1.3	Receive defective product
D3.11	Invoice and receive payment	DR1.4	Transfer defective product

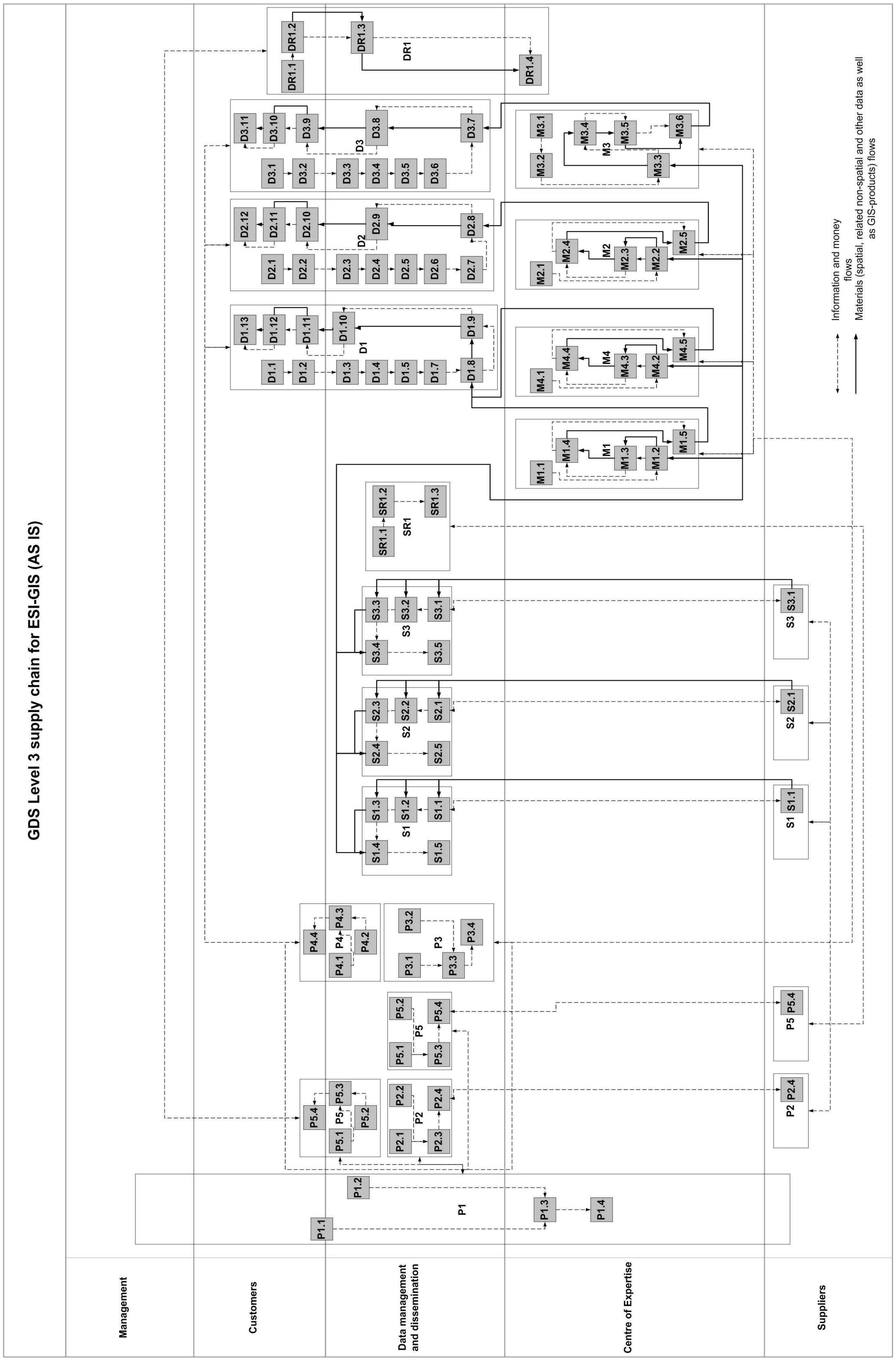

Figure 7.31: ESI-GIS AS IS GDS Level 3 supply chain

Once the supply chain at GDS Level 3 has been established, each process element is analysed using the different workbooks using the Staple-Yourself-to-an-Order methodology. As mentioned in Sections 5.2 and 7.2.5.2, these workbooks are designed to capture data on the performance of the supply chain using various performance metrics, current practices, possible improvements, problems (disconnects) and the procedure followed to execute the process element. The aim is to use the performance data to establish how well the process element functions within the supply chain and to establish the various disconnects within each process element and link them back to the problem statements as established in Section 7.4.3. Once these disconnects have been linked to the problem statement and the supply chain, ESI-GIS refers back to the workbooks to improve the procedures, practices and business rules so as to rectify the problem and improve the performance of the supply chain. All the workbooks that were used in this study are available on the accompanying CD (PhD/GDS Workbooks).

Table 7.29 gives an example of a process element (worksheet) in a workbook, with the data captured during the study.

Table 7.29: Extract of the MAKE workbook (Make-to-Stock)

Process Element: **Schedule production activities M1.1**		
Process Element Definition		
The setting up and running of the production of the GIS product. The plan includes resources and sources of spatial data required for the production.		
Line function/Department		
Performance Attributes	Metric	Values
Reliability	Schedule achievement[1]	80% on time
Responsiveness		
Flexibility		
Cost	Scheduled resource costs[2]	R60 000 pa
Assets	Capacity utilisation[3]	16%
Current Practices	Improvements	

3 times a year	To manage change in data (10%) –> Maintain-to-Stock
Once the GIS product has been delivered the next run is planned	Collaboration agreements with other GIS units to share work load, such as Stats SA and DBSA. Distributed workflow system -
Feedback meeting with customer with respect to errors and how to improve GIS product	
Test week of GIS product by client only ->(D) – Distribution (LAN, Citric Farm per Region) other on CD/DVD	
If OK then roll out the next week ->(D)	
Business Rules	**Improvements**
Data sourced from custodians, no third party involvement	
Honour copyright and copyright own GIS products	
Refresh business rules every 4 months	
Data that are made available are compliant with Eskom in-house standards which are based on ISO and national standards	

Inputs	Plan	Source	Make	Deliver	Return
Production plans	P3.4				
Scheduled receipts		S1.1 S2.1 S3.1			
Information feedback			M1.2 M1.3 M1.4 M1.5		
Equipment and facilities schedules and plans			EM.5		
Outputs	**Plan**	**Source**	**Make**	**Deliver**	**Return**
Production schedule	P3.2	S1.1 S2.1 S3.3		D1.3 D1.8	

Disconnects
Low capacity utilisation - To improve capacity utilisation by improving resource availability such

as staff as well as succession planning
Hardware capacity too low to handle high volumes of data, i.e. 1.2 TB data. Need at least 2 TB capacity for efficient and effective processing of data
Sourced data for rural and deep rural areas are of low quality with regard to currency and completeness

Process steps: Work breakdown structure is created or revisited (-> Maintain-to-Stock) Scheduling of tasks Assigning of resources to tasks Determine delivery date, which influences the schedule Final schedule Note: Data purchase is capital cost, maintenance and/or production. ESI-GIS carries the cost from November 2006

This example looks at the MAKE process category Make-to-Stock's (M1) process element "Schedule production activities" (M1.1). The workbook gives the definition of the process element. The first few entries in the worksheet are the various performance metrics such as "schedule achievement", of which 80% of all the production projects were on time for ESI-GIS. The cost of preparing and implementing the schedules was estimated at R60 000.00 per annum. For the final outcome, the value was adjusted to reflect the actual costs at the end of the 2006/7 financial year. The final scheduling cost for the 2006/7 financial year was R49 318.73. The capacity utilisation for this activity is set at 16%. Unfortunately there is no benchmarking data for the GIS unit available to test whether the capacity is being under or over-utilised for this type of activity.

The next set of information captured in the worksheet is the current practices at ESI-GIS used for scheduling production as well as suggested improvements to the current practices. These suggestions then form part of the supply chain improvement process. The production scheduling is done three times a year to coincide with the GIS product updating cycle for the Eskom regional offices, which is the core business of ESI-GIS. The small ad hoc projects are scheduled on a needs basis, hence the problem of ad hoc projects on the production schedule as mentioned in the disconnect analysis in Section 7.5.3.

With regard to the seven spatial data sets project, once the first production run and roll out for the year has been completed, the next cycle of production and roll out is scheduled. Part of the Make-to-Stock process is the process element “Produce and test” (M1.3), which needs to be scheduled since the testing of the GIS product (the seven spatial data sets) is scheduled for a week at the various Eskom regional offices. Although it overlaps with the delivery process category, it is seen as part of the GIS product production. The reason for this approach is that if errors are detected, they are immediately rectified. Once the aspects have been satisfied, the GIS product is delivered using the standard DELIVER process elements. A suggested improvement was to manage changes in data by moving that aspect to the Maintain-to-Stock (M4) process category, which can have a variable maintenance schedule depending on the availability of new data from the suppliers. The other improvement was to build collaboration agreements with other GIS units to share the GIS product production load similar to the distributed GIS product production as discussed in Section 4.4.

The business rules applying to Make-to-Stock are that ESI-GIS will not use data that has not been sourced from the original custodians as ESI-GIS is very copyright conscious, and that the GIS products should comply with the standards as set by ESI-GIS.

The next entry on the worksheet is the different disconnects experienced by ESI-GIS when scheduling the production, which are listed in Table 7.29. These disconnects related back to the disconnect analysis done in Section 7.4.3. The above process is followed for each process element as mapped in the AS IS GDS Level 3 supply chain of ESI-GIS as shown in Figure 7.31, as well as the different enable processes. The performance metric data are captured from these worksheets on a spreadsheet to assess the performance of the supply chain of ESI-GIS, which can be accessed on the accompanying CD (PhD/GDS Spreadsheets). These values are aggregated from GDS Level 3 to GDS Level 2 and GDS Level 1. Table 7.30a gives an example of the values captured at GDS Level 3 (P1.1 to P1.4) and aggregated to GDS Level 2 (P1) for PLAN.

Table 7.30a: GDS Level 3 performance analysis for PLAN

PLAN Performance Attribute	Metric	Plan the supply chain P1.1	P1.2	P1.3	P1.4	**P1**
Reliability (aim 100%)	Forecast Accuracy %[1]	70				
	Delivery Performance to customer request date %			79		
	Fill rate %			100		
	Perfect Order Fulfilment %			100	100	
	On-time delivery %				100	
	Supplier Delivery on-time Delivery Performance %					
	Production plan adherence %					
	Return forecast accuracy %					
	Plan reliability (%)					**89.8**
Responsiveness (as quick as possible)	Order fulfilment lead time		120			
	Total plan cycle time (days)[5]					**120**
Flexibility (as fast as possible)	Cumulative source/make cycle time (number of days)^		120		120	
	Total supply chain reponse time				120	
	Cumulative make cycle time (number of days)^					
	Orde management cycle time					
	Return capacity utilization					
	Flexibilty (days)					**120**
Costs (as low as possible)	Supply chain finance cost[2]	*R 46 400.00*			*R 46 400.00*	
	Supply chain planning costs[4]		R 299 529.08			
	Total supply chain cost (2006/7)			R 16 658 506.46		
	Material (hardware, software and spatial data) planning costs					
	Plan costs[6]					**R 299 529.08**
Assets	Return On Assets		n/a		n/a	
	Cash-to-Cash cycle time (assumption 1)[3]		1516	1516	1516	
	Cash-to-Cash cycle time (assumption 2)[3]		161	161	161	
	Asset turnover[3]			9.89		

The following comments are of importance to the performance metrics captured for P1 (Plan the supply chain):

[1] Developed a structured forecast spreadsheet, which allows the capturing of actual data for comparative purposes. The forecast spreadsheet is attached in Appendix C.

[2] Cost of ensuring from ESI-GIS's side that invoices, accounts receivable, etc. are being processed by the financial department of Eskom. Costs are absorbed in Source and Deliver.

[3] From ESI-GIS SCORcard (Table 7.24).

[4] Supply chain planning cost is 2% of total supply chain cost (it is 10% of the total labour costs (direct and indirect)).

[5] Most GIS products are completed within a four-month cycle, except Engineer-to-Order, which runs for a full year.

[6] Calculated from P1.1 and P1.2. The value of P1.2 is directly reflected as Planning Costs in the opportunity spreadsheet of ESI-GIS (Appendix C) under Total Supply Chain Management costs. It incorporates costs for P2, P3, P4 and P5.

The performance is measured at GDS Level 3 using the different metrics for each of the performance attributes. For example, the performance attribute “Reliability” in Table 7.30a consists of eight metrics ranging from forecasting accuracy to “Return forecast accuracy”. The values are determined for each metric and captured in the spreadsheet as shown in Table 7.30a. To calculate the reliability of “Plan the supply chain” at GDS Level 2, the metrics are aggregated by determining the average for all the captured metrics, which results in a reliability value of 89.8%, which is according to de la Rey (2007) very good, since ESI-GIS puts in a great effort to ensure that the right GIS products are delivered on time to the right customer. The planning cycle and the flexibility of the supply are 120 days respectively, which is based on the four-month cycle for supplying the seven spatial data sets to the various Eskom offices. The planning costs are R299 529.08; the Cash-to-Cash cycle time is either 1 516 or 161 days depending on the assumption as discussed in conjunction with Table 7.24 in Section 7.4.1; the asset turnover is 9.89, which means that for every R1.00 ESI-GIS invests, it makes R9.89. According to Bolstorff and Rosenbaum (2003), a high asset turnover indicates that an organisation utilises its assets well, and in the example they used the asset turnover was 1.5. Thus an asset turnover of 9.89 indicates that ESI-GIS uses its assets very well. Since there is currently no benchmarking data available for the GIS industry at large, it cannot be determined whether an asset turnover of 9.89 is above or below the norm in the GIS industry. Although according to Bolstorff and Rosenbaum (2003) a long Cash-to-Cash cycle indicates problems with regard to cash utilisation, it could not be determined whether such a value indicates the norm in the GIS industry. In Table 7.25a some of the metrics have no values for P1.1 to P1.4, which is due to the fact that these metrics are applicable to P2 (Plan SOURCE), P3 (Plan Make), P4 (Plan DELIVER) and P5 (Plan RETURN), which are not shown in this example.

Table 7.30b gives an example of the data captured for SOURCE at GDS Level 3.

Table 7.30b: GDS Level 3 performance analysis for SOURCE

SOURCE Performance Attribute	Metric	Source Stocked Product					
		S1.1	S1.2	S1.3	S1.4	S1.5	**S1**
Reliability (aim 100%)	Delivery performance (supplier)%	0					
	% orders received complete		70				
	% orders received on time to demand requirement		30				
	Defective free orders (suppliers)%			40			
	Invoices processed without issues or errors (ESI-GIS)%					80	
	Potential suppliers selected which become qualified %						
	Qualified suppliers which met defined requirements %						
	Percentage supplier contracts negotiated meeting target terms and conditions for quality, delivery, flexibility and cost						
	Sourcing reliability (%)						**44**
Responsiveness (as quick as possible)	Order fulfillment lead time in days (supplier)	23					
	Receiving cycle time (ESI-GIS)		1				
	Verification cycle time (ESI-GIS)			5			
	Transfer cycle time (ESI-GIS)				3		
	payment cycle time (ESI-GIS)					90	
	Source identification and qualification time (ESI-GIS)						
	Source selection cycle time						
	Total source cycle time to completion (days)[1]						**32**
Flexibility (as fast as possible)	Time and/or cost reduction related to source identification						
	Percentage single and/or sole source selections						
Costs (as low as possible)	Product acquisition management costs expressed as % of product acquisition costs	4.2					
	Receiving costs as a % of product acquisition costs		20.8				
	Verification costs as a % of product acquisition costs			20.8			
	Transfer costs as a % of product acquisition costs				3.4		
	Product process engineering as a % of product acquisition costs						
	Sourcing costs as a % of product acquisition costs						
	Product acquisition costs						**R 520 059.96**
Assets	Value of assets provided by service provider (cost avoidance)[2]						

Total product acquisition costs [3] R 1 057 032.45

[1] Excludes payment cycle times.

[2] ESI-GIS could not give a monetary amount but estimates a saving between 100% and 150% with regard to certain GIS products purchased than if ESI-GIS had produced the same GIS product in-house.[3] From opportunity spreadsheets.

Owing to the lack of benchmarking data for the GIS industry, it is difficult to establish whether these values are below or above the norm. However, the sourcing reliability can be improved through relationship management, which is part of supply chain management as discussed in Chapter 2. In ESI-GIS, according to de la Rey (2007), each GIS employee is allocated a number of projects to create various GIS products and is also responsible for sourcing the data needed to create these products, which explains the high labour cost of acquiring the data. The reduction of labour costs for sourcing is seen as an opportunity to improve the supply chain (see Table 7.27).

An example of the MAKE GDS Level 3 performance analysis is given in Table 7.30c. Despite the problems experienced with the reliability of their suppliers, ESI-GIS still manages to complete the GIS product 80% of the time within the scheduled time scale. The absence of a properly installed data warehouse influences the reliability of Make-to-Stock production. The total production cycle time for Make-to-Stock GIS products is 103 days and the production costs are R453 732.31 with a capacity utilisation of 38%. Capacity utilisation according to the Supply-Chain Council (2001: 237) is the "*measure of how intensively a resource is being used to produce a good or service.*" Owing to the nature of the GIS products created by ESI-GIS, it is necessary for the person to be involved in the planning, sourcing and delivery of the GIS product as well, which is a hindrance to that person in producing a GIS product. Thus the value of capacity utilisation in the context of ESI-GIS of 38% may actually be a good value since a person only spends 50% of his/her time on creating a GIS product. Only through the use of industry-wide benchmarking data, which is not available at present, can it be determined whether a capacity utilisation of 38% is good or not. This value may improve in the future since it is one of the areas where ESI-GIS sees an opportunity to improve the supply chain (see Table 7.27).

Table 7.30c: GDS Level 3 performance analysis for MAKE

MAKE Performance Attribute	Metric	Make to Stock					
		M1.1	M1.2	M1.3	M1.4	M1.5	**M1**
Reliability (aim 100%)	Schedule achievement % on time	80					
	Inventory accuracy		0				
	Fill rates %			90			
	Ratio of actual to theoretical cycle time %			67			
	Warrenty and returns (% not returned by customer)			90			
	Placement time of GIS-product in data warehouse				30		
	Percent of orders scheduled to customer request date						
	Number of model changes before model finalisation[4]						
	Production reliability (%)						**60**
Responsiveness (as quick as possible)	Data warehouse accessibility (days)[1]		1				
	Total built time (days)			90			
	GIS-prtoduct change over time			10			
	Release process cycle time					2	
	Production engineering time (days)						
	Total production cycle time to completion (days)[1]						**103**
Flexibility (as fast as possible)							
Costs (as low as possible)							
	Scheduled resource costs	R 49 318.73					
	Total production employment			R 147 956.19			
	Value added employment productivity			R 157 819.93			
	Warranty costs			R 98 637.46			
	Release costs[3]					R 0.00	
	Model changes costs						
	Production costs						**R 453 732.31**
Assets	Capacity utilisation %	16		59			**38**
	Cash-to-Cash cycle time (assumption 1)[2]		1516				**1516**
	Cash-to-Cash cycle time (assumption 2)[2]		161				**161**

The following comments are of importance to this analysis:

[1] Includes searching for data on RHD, DVD or CD-ROM.

[2] From ESI-GIS SCORcard, Table 7.24.

[3] Not available, the value is currently part of the production labour costs.

[4] Four iterations are currently done by ESI-GIS before the final product design (model) is accepted. If the model is completed within two iterations = 100%, thus 4 = 50%, the aim is to have as low a number of iterations as possible to save on labour costs (this applies only to MAKE Engineer-to-Order GIS products).

Table 7.30d gives a performance analysis of the delivery of a stocked product to the customer as an example of the GDS Level 3 performance analysis of DELIVER, which will be discussed next.

Table 7.30d: GDS Level 3 performance analysis for DELIVER

DELIVER Performance Attribute	Metric	Deliver Stocked Product						
		D1.1[2]	D1.2	D1.3	D1.4	D1.5	D1.6[3]	D1.7[4]
Reliability (aim 100%)	Number of call-backs as % of total inquiries	100						
	Delivery performance to customer commit date %			90				
	Order consolidation profile				n/a			
	Fill rates							
	Delivery performance to customer commit date %							
	Delivery performance to customer request date %							
	Perfect order fulfillment %							
	Percentage faultless installation							
	Delivery reliability (%)							
Responsiveness (as quick as possible)	Customer signature/authorization to order receipt time (days)		1					
	Order receipt to order entry complete time		1					
	Order receipt to order entry complete time (days)			1				
	Order entry complete to order ready for shipment date (days)				1			
	Order entry complete to start manufacture time (days)							
	Order ready for shipment to customer receipt of order time (days)							
	Customer receipt of order to installation complete (days)							
	Total delivery cycle time (days)							
Flexibility (as fast as possible)								
Costs (as low as possible)	Order management costs[1]	R 177 080.94						
	Create customer order costs (see [1])							
	Order entry and maintenance costs (see[1])							
	Order fulfilment costs (see[1])							
	Planned transportation costs (not part of cost calculation)				R 8 400.00			
	Actual transportation costs[9]					R 8 400.00		
	Distribution costs[10]							
	Delivery costs							
Assets								

Performance Attribute	Metric							
		D1.8	D1.9[5]	D1.10	D1.11	D1.12	D1.13[6]	**D1**
Reliability (aim 100%)	Number of call-backs as % of total inquiries							
	Delivery performance to customer commit date %							
	Order consolidation profile							
	Fill rates		100					
	Delivery performance to customer commit date %			90				
	Delivery performance to customer request date %			90				
	Perfect order fulfillment %			90	90			
	Percentage faultless installation							
	Delivery reliability (%)							**93**
Responsiveness (as quick as possible)	Customer signature/authorization to order receipt time (days)							
	Order receipt to order entry complete time							
	Order receipt to order entry complete time (days)							
	Order entry complete to order ready for shipment date (days)		1	1	1			
	Order entry complete to start manufacture time (days)							
	Order ready for shipment to customer receipt of order time (days)							
	Customer receipt of order to installation complete (days)							
	Total delivery cycle time (days)							**7**
Flexibility (as fast as possible)								
Costs (as low as possible)	Order management costs[1]							
	Create customer order costs (see [1])							
	Order entry and maintenance costs (see[1])							
	Order fulfilment costs (see[1])							
	Planned transportation costs (not part of cost calculation)							
	Actual transportation costs[9]							
	Distribution costs[10]		n/a					
	Delivery costs							**R 185 480.94**
Assets								

The following comments must be taken into account when interpreting the performance analysis:

[1] Includes the costs for D1.1, D1.2 and D1.3 for D1. Includes the costs for D3.1, D3.2 and D3.3 for D3.

[2] In 2006/7 there were 120 orders.

[3] Not applicable to ESI-GIS.

[4] ESI-GIS must use Eskom's preferred courier service.

[5] Products are selected from removable hard disks and copied onto CD-ROM or DVD.

[6] Invoicing and receiving payment is an Eskom corporate financial function: ESI-GIS notifies the financial department to invoice customer.

[7] Data routing is done via a dedicated central server.

[8] This includes airline costs as well. Costs included with distribution costs.

[9] Part of SG&A costs.

[10] For D2.5 it includes labour and subsistence and travel costs since the GIS products are delivered in person by ESI-GIS.

ESI-GIS has a high delivery reliability of 93% for stocked GIS products. Most of these GIS products are ad hoc projects, where ESI-GIS is requested to provide a GIS product such as the medium-voltage electricity grid or Eskom's schools data which indicate if a school has access to electricity or not (de la Rey, 2006). In the example used by Bolstorff and Rosenbaum (2003) a delivery reliability of 95% was seen as superior, thus it can be assumed that ESI-GIS's delivery reliability of 93% is superior, but this needs to be confirmed through the use of benchmarking data from the GIS industry. The total delivery cycle time for stocked GIS products is seven days and the total delivery cost for stocked GIS products for the 2006/7 financial year was R185 480.94. Order management costs are listed here as labour costs. The total labour costs for DELIVERY is 10% of the total labour cost of the supply chain. For ESI-GIS this is an acceptable value since in the large projects such as the seven spatial data sets, the GIS staff members have to deliver and install the relevant GIS products in person.

The last management process that will be discussed is RETURN. Table 7.30e gives an example of the GDS Level 3 analysis of RETURN, namely Source Return of defective data that ESI-GIS received from their suppliers. The costs for Source Return are currently part of the sourcing costs, which are given in Table 7.30b.

The reliability with regard to Source Return is given as the percentage of received data from suppliers that have not been returned by ESI-GIS, which was 77% for this financial year. Thus only 23% of the orders were returned by ESI-GIS. The return cycle is 25 days, which will have an impact on production and delivery of the GIS product to the customer. The flexibility of the supply chain with regard to return is 15 days. Flexibility is an indication of how quickly the supply chain responds to change. The high return costs are due to fact that ESI-GIS has to prove to the supplier that the supplier did indeed deliver a faulty product. The value of the faulty GIS products that were to be destroyed is R70 000.00, whereas the GIS products with a value of R126 000.00 were still awaiting the go-ahead to be destroyed once the supplier had agreed to replace the faulty product.

The above were examples of the performance analysis of the various GDS Level 3 process elements and GDS Level 2 process categories. The same was done for the remaining process elements for each GDS Level 2 process category. Appendix C gives the printout of the all the performance analyses that were done for ESI-GIS.

Table 7.30e: GDS Level 3 performance analysis for RETURN

RETURN Performance Attribute	Metric	Source RETURN					
		SR1.1	SR1.2	SR1.3	SR1.4[2]	SR1.5[2]	SR
Reliability (aim 100%)	Total authorisations requested, expressed as % not requested			77			
	Percentage of defective GIS-products (or other data) received correctly and on time %						
	Return reliability (%)						**77**
Responsiveness (as quick as possible)	Cycle time from problem identification to condition confirmation (days)	5					
	Cycle time to reach return to supplier authorisation or when supplier indicates that the GIS-product or other data will be replaced and thus allowing for the removal of the defective item from the data warehouse (days)		15				
	Cycle time from the customer (the GIS unit) identifying the need and signalling for a return authorisation to the confirmation of authorisation for return by the supplier or informing the supplier that the data will be deleted and destroyed (days)			5			
	Response cycle time (days)						
	Return authorisation schedule creation time (days)						
	Receiving cycle time (days)						
	Total return cycle time (days)						**25**
Flexibility (as fast as possible)	Cycle time to change condition criteria (days)	15					
	Time to expiditing the disposition[1]						
	Cycle time to incorporate changes in return authorisation processing			n/a			
	Cycle time to update changes to shipment schedule						
	Flexibilty (days)						**15**
Costs (as low as possible)	Cost of identifying the defective condition	R 50 000.00					
	Defective GIS-product or other data disposition costs[1]						
	Authorisation costs			R 150 000.00			
	Authorisation to return and replace defective delivered GIS-product costs						
	Defective product Deliver Return costs						
	Receiving costs as a percentage of total Deliver Return costs[3]						
	Return costs						**R 200 000.00**
Assets	Value of defective GIS-product or other data in the data warehouse	R 70 000.00					
	Value of the GIS-product or other data that is ear marked for disposition or removal	R 126 000.00		R 126 000.00			
	Value of defective GIS-product (or other data) that awaits authorisation						
	Value of defective GIS-product or other data that is scheduled for receipt						
	Value of defective GIS-products (or other data) received from customers						

The following four comments should be kept in mind when interpreting the Source and Deliver Return GDS Level 3 performance analysis:

[1] No time and cost spent since data are simply deleted and destroyed.

[2] ESI-GIS does not return faulty sourced GIS products and data.

[3] Costs included in DR1.2.

[4] No data available, the correction of faulty data is scheduled as M4 (Maintain-to-Stock).

At GDS Level 1 (see Table 7.31), ESI-GIS's supply chain reliability is 76%, which indicates that 76 out of 100 projects will be delivered according to the expectations set by ESI-GIS and the customer. Since supply chain management has a philosophy of continuous improvement as demonstrated in Chapter 2, which means that it strives for 100% supply chain reliability, the result indicates that there is a need to improve the supply chain. Whether the supply chain reliability of ESI-GIS is below or above the norm in the GIS industry cannot be determined owing to the lack of benchmarking data. The total supply chain cycle time is 397 working days, which indicates that it is longer than a financial year. Since projects do overlap, it is possible that fewer actual days are spent on creating the GIS products than indicated in the supply chain. The total cost of the supply chain indicated excludes the data costs of R13 067 769.07 and R378 314.44 of sales, general and administration (SG&A) such as levies, stationary and conference meetings that are not reflected in Tables 7.30a-e and 7.31 since they do not impact on the supply chain performance of ESI-GIS. ESI-GIS can reduce the costs by finding suppliers who can provide the data at a lower price than the current suppliers. The same can be done to lower the SG&A costs.

Table 7.31 gives a summary of the performance analysis that can be used as part of improving the supply chain.

Table 7.31: Summary performance of ESI-GIS's supply chain (GDS Level 1)

Performance attribute	*Reliability (aim 100%)*	*Responsiveness (as quick as possible)**	*Flexibility (as fast as possible)**	*Costs (as low as possible)*	*Assets*
GDS Level 1					
Management process					
PLAN	83	120	71	R 299 529.08	
SOURCE	49	139	100.00%	R 1 057 032.45	
MAKE	65	101		R 1 497 645.41	43
DELIVER	92	22		R 358 216.01	
RETURN	89	15	15		
	76	**397**		**R 3 212 422.95**	**43**

*In number of working days unless otherwise indicated.

The next step is to link the identified disconnects in the GDS Level 3 process element analyses to the original disconnect analysis results as discussed in Section 7.4.3. Table 7.32 lists disconnects that were linked back to the disconnect analysis in Section 7.4.3, as well as the process elements where these disconnects have been identified. The reference numbers (Ref.) in the table are used to indicate where these disconnects occur in the TO BE GDS

Level 3 supply chain map. This will be used as part of supply chain management to improve the chain.

Table 7.32: GDS Level 3 process element disconnects linked to original disconnects (Priority 1)

Ref.	**GDS Process element**	**Problem description as per disconnect analysis (Figures 7.25 to 7.29)**
1	D1.1	Customers do not know what they actually need
2	M1.1, M4.1	Wrong personnel do the wrong work on the project
3	P1, P5.1	Customer not included in the planning process
4	M1.2, M1.3, M2.2, M2.3, M3.3, M3.4, M4.2, M4.3	Do not know what data are available
5	M1.4, M2.4, M3.5, M4.4	Metadata not centralised
6	S1.4, S2.4, S3.6, ES.4, P3.1	Data availability
7	S1.2, S1.3	Faulty data from suppliers
8	S1.2, S1.3	Non-adherence to regulatory requirements
9	M1.3, M2.3, M3.4, M4.3	ISO processes not updated
10	M1.1, M3.2, M4.1	Poor data quality
11	S2.3, M1.3, M2.3, M3.4, M4.3	Non-compliance with data standards
12	M3.2	Interruptions caused by sudden reallocation of personnel to work on another “more urgent” project
13	M1.4, M2.4, M3.5, M4.4	Not adhering to standard operating procedures
14	M1.5, M2.5, M3.6, M4.5	Inadequate quality control measures/quality control not enforced properly
15	M1.5, M2.5, M3.6	Process is not documented as required
16	M1.4, M2.4, M3.5, M4.4	Non-compliance with data standards
17	M1.4, M2.4, M3.5, M4.4	Missing metadata
18	M1.3, M2.3, M3.2, M3.4, M4.3	Lack of advanced GIS skills
19	ES.5, M1.1, M3.2, M2.1, M4.1	Slow PCs
20	P3.2	Inadequate resources/not enough personnel to do the work
21	M2.3, D2.1	Lack of skills on customer’s side to use delivered data
22	D2.11	Lack of necessary skills/procedures to successfully sign off the delivered data
23	D2.1	Customers unwilling to sign off data owing to their own lack of understanding of their data needs
24	P4.2	Inadequate delivery mechanisms
25	ED.6, P4.4	Courier service
26	S3.1, S3.2, ES.9	Procurement delays impact on planning of projects
27	M3.1, D3.2	Eskom financial processes are insufficient to support funding of specific projects
28	S1.1, S2.1	Time it takes to receive data

Ref.	GDS Process element	Problem description as per disconnect analysis (Figures 7.25 to 7.29)
29	S1.5, S2.5, S3.7	Eskom financial processes impact on the delivery of completed GIS products/ Eskom financial processes not clearly understood
30	ES.1	Corporate financial process/Eskom financial processes not clearly understood
31	ES.4	Data resources not planned thoroughly
32	ES.4	Lack of database management skills

During the linkage exercise it was discovered that some of the disconnects that were indicated in either the original disconnect exercise or in the GDS Level 3 process element data gathering exercise could not be linked. These disconnects are listed in Table 7.33.

Table 7.33: "Priority 2 Problems"

Ref.	Problem description
33	No communication with the client
34	If there is communication, there is an inability to provide progress reports
35	Project planner does not know what the customer actually needs
36	Duplication of data
37	Ad hoc requests impact on delivery of longer-term projects
38	Lack of planning on customer's side, which leads to ad hoc requests
39	Out-dated data or wrong version
40	Wrong data formats
41	ESI-GIS to carry costs for supplier to correct faulty data
42	Wrong projections
43	Wrong datums
44	ISO meetings are not being held any more
45	Wrong data formats
46	Poor data management during project execution
47	Unnecessary pre-processing of data due to correcting faulty data
48	Accountability for data not taken
49	Inadequate time allocated to execute project
50	Limited software availability due to license restrictions
51	Network problems
52	LAN availability is problematic
53	Existing data server not always available
54	CD-ROMs too small for certain data sets
55	Data size restricted to 2 MB

Ref.	Problem description
56	No map server available
57	Customer does not keep track of changes in data sets delivered
58	ESI-GIS sends the wrong version to clients
59	Not always on time with delivery
60	Reliable but high costs involved
61	Transporting the data from suppliers to ESI-GIS
62	Unwillingness to share data

It was concluded that although it is important to solve all these identified disconnects, those that are identified in both exercises should be classified as Priority 1 disconnects and the rest as Priority 2 disconnects. ESI-GIS should solve the Priority 1 disconnects first before addressing the Priority 2 disconnects. Using the opportunities, the AS IS GDS Level 3 supply chain and both the identified Priority 1 and Priority 2 disconnects, a TO BE GDS Level 3 supply chain is developed. This TO BE supply chain is discussed in the next section.

7.5.4.3 Mapping the TO BE supply chain at GDS Level 3

From the opportunities identified, namely improving the quality of the data and the production of GIS products, the mapping of the AS IS GDS Level 3 supply chain as well as both the identified Priority 1 and Priority 2 disconnects, the following were defined:

- From the analysis it was not clear who is responsible for data acquisition, which was being done on an informal basis answering to needs.
- There is no formal data management nor a data warehouse. Data that have been sourced are stored on various media such as removable hard disks, DVDs and CD-ROMs.
- Although ESI-GIS has very good delivery mechanisms in place, it was decided that it should have a line function to deal with the delivery of GIS products since this currently involves GIS-trained staff members travelling to customers, which takes them out of the production cycle.

The supply chain was revised by changing the number of functions from five (including the customers and suppliers) to seven to address the above concerns. Although staff members who produce GIS products are involved with the planning, sourcing of data and the delivery of completed GIS products to customers, formalising the two new functions would improve the acquisition and dissemination of the data and GIS products in the supply chain, since it can then be planned and managed properly as part of managing the supply chain. The formalising of the acquisition and dissemination of the data could involve the appointment of an administrative person to administer acquisition and dissemination, such as placing orders, follow-up of the orders placed, organising travel and subsistence and organising couriers to deliver the GIS products. This would free the production staff from administrative work and allow more production time. This would also force ESI-GIS to involve their suppliers and customers as part of their planning processes to ensure a more efficient and effective supply chain. Figure 7.32 gives the GDS Level 3 TO BE supply chain for ESI-GIS. Database management, which includes the data warehouse, is a separate function within ESI-GIS's TO BE supply chain, and ESI-GIS appointed a person from 1 April 2007 to manage this function and the data warehouse. A properly managed inventory and data warehouse would enable ESI-GIS to acquire the necessary data for production more efficiently.

To enable ESI-GIS to manage the TO BE supply chain, the identified disconnects should be prioritised to establish which of them should be addressed and managed first to improve the efficiency and effectiveness of the TO BE supply chain. From the opportunity analysis, it was decided that only the production process should be addressed by improving data quality and production. At GDS Level 3, it is all those process elements involved with SOURCE and MAKE, and in a few cases it also involves a few elements from PLAN and DELIVER.

As mentioned in Section 7.4.4.2, ESI-GIS should first address the different Priority 1 disconnects to improve the efficiency and effectiveness of its TO BE supply chain, and once the Priority 1 problems have been addressed, ESI-GIS can put a strategy in place to address the Priority 2 disconnects. For the purpose of this study only the Priority 1 disconnects were prioritised to establish which of them would have the biggest impact on improving the efficiency and effectiveness of the TO BE supply chain.

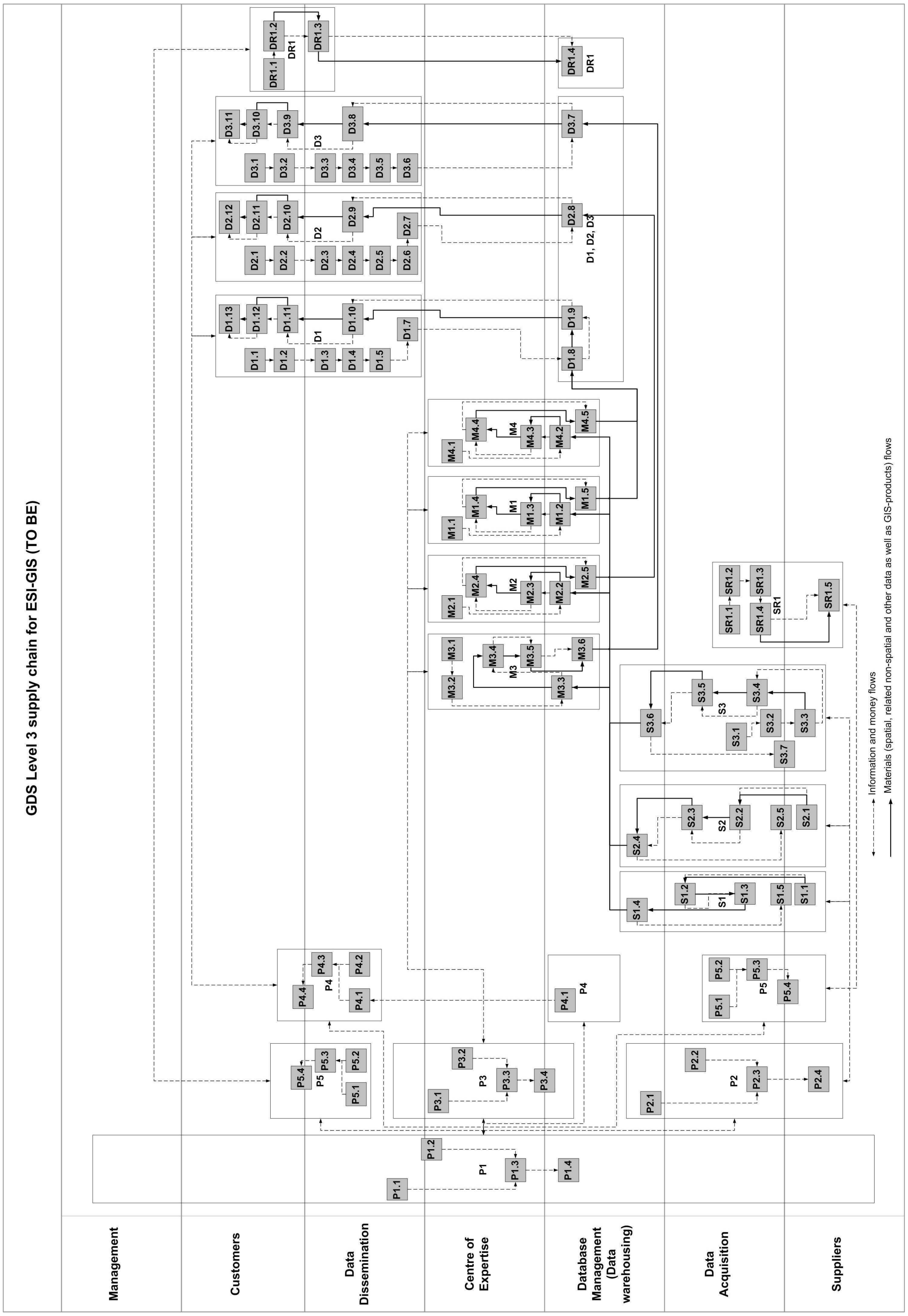

Figure 7.32: ESI-GIS TO BE GDS Level 3 supply chain

The first step is to identify the different disconnects that need to be addressed first. These are the Priority 1 disconnects directly linked to SOURCE and MAKE (see Table 7.34). The second step is to identify those disconnects that would have the biggest impact on the supply chain if they were solved first.

Table 7.34: First prioritisation of Priority 1 disconnects

Ref.	SCOR Process element	Problem description
MAKE		
20	P3.2	Inadequate resources/not enough personnel to do the work
4	M1.2, M1.3, M2.2, M2.3, M3.3, M3.4, M4.2, M4.3	Do not know what data are available
5	M1.4, M2.4, M3.5, M4.4	Metadata not centralised
2	M1.1, M4.1	Wrong personnel do the wrong work on the project
9	M1.3, M2.3, M3.4, M4.3	ISO processes not updated
10	M1.1, M3.2, M4.1	Poor data quality
12	M3.2	Interruptions caused by sudden reallocation of personnel to work on another “more urgent” project
13	M1.4, M2.4, M3.5, M4.4	Not adhering to standard operating procedures
14	M1.5, M2.5, M3.6, M4.5	Inadequate quality control measures/quality control not enforced properly
15	M1.5, M2.5, M3.6	Process is not documented as required
16	M1.4, M2.4, M3.5, M4.4	Non-compliance with data standards
17	M1.4, M2.4, M3.5, M4.4	Missing metadata
18	M1.3, M2.3, M3.2, M3.4, M4.3	Lack of advanced GIS skills
19	M1.1, M3.2, M2.1, M4.1	Slow PCs
21	M2.3	Lack of skills on customer’s side to use delivered data
27	M3.1	Eskom financial processes are insufficient to support funding of specific projects
11	M1.3, M2.3, M3.4, M4.3	Non-compliance with data standards
SOURCE		
11	S2.3	Non-compliance with data standards
6	S1.4, S2.4, S3.6, ES.4, P3.1	Data availability
7	S1.2, S1.3	Faulty data from suppliers
8	S1.2, S1.3	Non-adherence to regulatory requirements
26	S3.1, S3.2, ES.9	Procurement delays impact on planning of projects
28	S1.1, S2.1	Time it takes to receive data
29	S1.5, S2.5, S3.7	Eskom financial processes impact on the delivery of completed GIS products/Eskom financial processes not clearly understood
30	ES.1	Corporate financial process/ Eskom financial processes not clearly understood

Ref.	SCOR Process element	Problem description
31	ES.4	Data resources not planned thoroughly
32	ES.4	Lack of database management skills
19	ES.5	Slow PCs
Other		
24	P4.2	Inadequate delivery mechanisms
25	ED.6, P4.4	Courier service
22	D2.11	Lack of necessary skills/procedures to successfully sign off the delivered data
23	D2.1	Customers unwilling to sign off data owing to their own lack of understanding of their data needs
1	D1.1	Customers do not know what they actually need
3	P1, P5.1	Customers not included in the planning process
21	D2.1	Lack of skills on customer's side to use delivered data
27	D3.2	Eskom financial processes are insufficient to support funding of specific projects

The second prioritisation is based on the ABC analysis as discussed in Section 7.2.5.3. Table 7.35 gives the classification of the different disconnects. The classification is done by determining the costs using the GDS Level 3 process elements performance analysis spreadsheets, which were discussed in Section 7.4.4.2. From the opportunity spreadsheets it was concluded that if the data quality could be improved it should have a 10% impact on the labour costs, and when solving the production problems ESI-GIS should achieve a 3% savings in labour costs. To establish which disconnect should be solved, the costs are then reduced to either 10% or 3% based on where the different disconnects will have an impact on data quality ("Poor data" in Figure 7.26) or production ("Production problems" in Figure 7.27).

According to Table 7.35, seven of the 32 identified Priority 1 disconnects will have an impact of just over 80% on the supply chain's efficiency and effectiveness if they are addressed first. These are in descending order:

- 11: Non-compliance with data standards
- 7: Faulty data from suppliers
- 8: Non-adherence to regulatory requirements
- 10: Poor data quality

- 18: Lack of advanced GIS skills
- 4: Do not know what data are available
- 9: ISO processes not updated.

Table 7.35: Classification of Priority 1 disconnects

Ref.	GDS Level 3 process element	Cost[1]	Impact[2]	Percent	Sub-total	Class[3]
11	M1.3, M2.3, M3.4, M4.3	R 823 622.76	R 82 362.28	23.59%		A
7	S1.2, S1.3	R 439 725.50	R 43 972.55	12.60%		A
8	S1.2, S1.3	R 439 725.50	R 43 972.55	12.60%		A
10	M1.1, M3.2, M4.1	R 394 549.84	R 39 454.98	11.30%		A
18	M1.3, M2.3, M3.2, M3.4, M4.3	R 922 260.22	R 27 667.81	7.93%		A
4	M1.2, M1.3, M2.2, M3.3, M3.4, M4.2, M4.3	R 823 622.76	R 24 708.68	7.08%		A
9	M1.3, M2.3, M3.4, M4.3	R 823 622.76	R 24 708.68	7.08%	82.17%	A
19	M1.1, M3.2, M2.1, M4.1	R 624 703.92	R 18 741.12	5.37%		B
2	M1.1, M4.1	R 295 912.38	R 8 877.37	2.54%		B
1	D1.1	R 177 080.94	R 5 312.43	1.52%		B
6	S1.4, S2.4, S3.6, ES.4, P3.1	R 52 851.62	R 5 285.16	1.51%		B
11	S2.3	R 48 623.49	R 4 862.35	1.39%		B
12	M3.2	R 98 637.46	R 2 959.12	0.85%		B
26	S3.1, S3.2, ES.9	R 97 246.98	R 2 917.41	0.84%		B
3	P1, P5.1	R 89 858.70	R 2 695.76	0.77%	14.80%	B
21	M2.3	R 86 307.77	R 2 589.23	0.74%		C
23	D2.1	R 59 026.98	R 1 770.81	0.51%		C
21	D2.1	R 59 026.98	R 1 770.81	0.51%		C
28	S1.1, S2.1	R 53 908.65	R 1 617.26	0.46%		C
27	M3.1	R 49 318.73	R 1 479.56	0.42%		C
20	P3.2	R 14 976.45	R 449.29	0.13%		C
24	P4.2	R 14 976.45	R 449.29	0.13%		C
25	ED.6, P4.4	R 14 976.45	R 449.29	0.13%		C
5	M1.4, M2.4, M3.5, M4.4	R 0.00	R 0.00	0.00%		C
13	M1.4, M2.4, M3.5, M4.4	R 0.00	R 0.00	0.00%		C
14	M1.5, M2.5, M3.6, M4.5	R 0.00	R 0.00	0.00%		C
15	M1.5, M2.5, M3.6	R 0.00	R 0.00	0.00%		C
16	M1.4, M2.4, M3.5, M4.4	R 0.00	R 0.00	0.00%		C
17	M1.4, M2.4, M3.5, M4.4	R 0.00	R 0.00	0.00%		C
29	S1.5, S2.5, S3.7	R 0.00	R 0.00	0.00%		C
30	ES.1	R 0.00	R 0.00	0.00%		C
31	ES.4	R 0.00	R 0.00	0.00%		C
32	ES.4	R 0.00	R 0.00	0.00%		C
19	ES.5	R 0.00	R 0.00	0.00%		C
22	D2.11	R 0.00	R 0.00	0.00%		C
27	D3.2	R 0.00	R 0.00	0.00%	3.03%	C
			R 349 073.81		100.00%	

[1] Actual costs as identified during the GDS Level 3 process element level analysis.

[2] Actual cost for each process element times the percentage improvement which is either 10% when the identified disconnect was applicable to the "Poor data" unique problem statement or 3% if the disconnect was linked to the "Poor production" unique problem statement.

[3] Indicates into which class it falls based on the ABC analysis.

Once the class A Priority 1 disconnects have been addressed, ESI-GIS can then address the class B Priority 1 disconnects and finally the class C Priority 1 disconnects. Figure 7.33 below show where these Priority 1 disconnects are having an impact on ESI-GIS's GDS Level 3 TO BE supply chain.

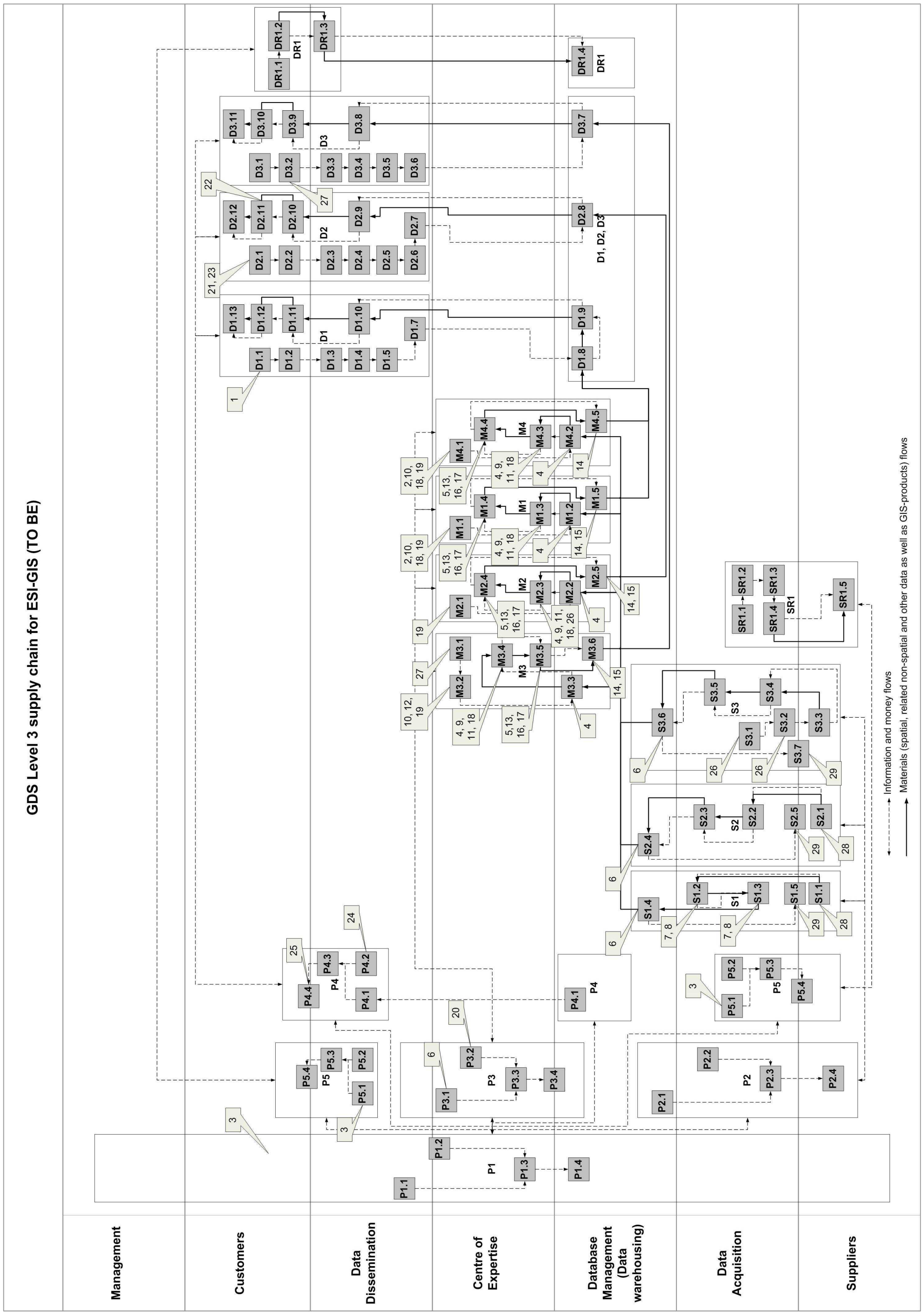

Figure 7.31: ESI-GIS TO BE GDS Level 3 supply chain with disconnects

7.6 Conclusions

The aim of this research was to establish whether the use of supply chains and supply chain management can be used to improve the efficiency and effectiveness of GIS units. From the discussions in Chapters 2 to 5, it was concluded that the possibility does exist that supply chains and supply chain management can improve the efficiency and effectiveness of GIS units.

To be able to prove that supply chains and supply chain management do in fact improve the efficiency and effectiveness of a GIS unit, it was necessary to identify a GIS unit, which was ESI-GIS (see Chapter 6), and to develop a model to analyse and model the supply chain of ESI-GIS. The model that was used was the Supply-Chain Operations Reference (SCOR) model developed by the Supply-Chain Council. The SCOR model is discussed in Section 2.5.

The standard SCOR model was used in the 2004/5 study to analyse and model the supply chain of ESI-GIS and to provide inputs to improve the supply chain through supply chain management. It was, however, discovered that the SCOR model as developed by the Supply-Chain Council could not be used as such and it was concluded that to use the SCOR model successfully it would have had to be adjusted for the GIS environment. To adjust the SCOR model during the 2004/5 study would have been a lengthy process, and it was decided to stop the study at SCOR Level 2 and show the areas of improvements at this level, which gave sufficient guidance to ESI-GIS to start improving their supply chain. Marais (2005) indicated that it is not an unusual practice to stop at a SCOR Level 2 analysis, provided the improvements that are based on the information gathered at this stage are significant.

The SCOR model was then adjusted for use in the GIS context as discussed in Section 7.4, and the study was repeated in 2006/7. The adjusted model is the GISDataSCOR (GDS) model, which enabled the researcher to analyse and model ESI-GIS's supply chain at all three levels as in the original SCOR model, which then provided the basis for ESI-GIS to improve its supply chain by managing the supply chain's performance and solving the identified problems.

From the results of the 2004/5 and especially the 2006/7 study as discussed in Sections 7.3 and 7.4, it is concluded that the use of supply chains and supply chain management will improve the efficiency and effectiveness of a GIS unit. Use of the GDS model approach enables the GIS unit to analyse and model its supply chain in a structured manner, to measure the performance of its supply chain and to establish problem areas within the supply chain and to turn them into opportunities to improve the supply chain through supply chain management.

To enable a GIS unit to fully understand its competitiveness within the GIS industry, it is necessary to benchmark its supply chain performance against other GIS units which do similar work. Unfortunately there is currently no such benchmarking data available, and it was concluded that the development of such benchmarks was outside the scope of this research. By concentrating on ESI-GIS's supply chain performance, it was more than sufficient to guide ESI-GIS to improve its supply chain. It is, however, recommended that such benchmarks should be established in the GIS industry and made available on an annual basis so as to enable GIS units to benchmark their supply chain performance against that of their peers.

It is further concluded that by adhering to the original SCOR philosophy of making supply chain modelling and analysis as accessible as possible by developing a paper-based system (Supply-Chain Council, 2001), the GDS model and methodology does not need sophisticated software to enable a GIS unit to analyse and model its supply chain and to provide input for good supply chain management. The GDS model is thus accessible to every GIS unit irrespective of its size and financial situation.

The final conclusion is that supply chains and supply chain management offer a GIS unit an improved workable alternative for managing its GIS product production according to current management practices as presented in the current GIS literature. Thus answering objective E as formulated in Section 1.5.

Chapter 8: Synthesis

8.1 Introduction

The aim of the research was to find an answer to the following research objective as formulated in Section 1.5:

> ***Can the establishment of supply chains and the utilisation of supply chain management assist a GIS unit to be more efficient and effective in the use of GIS when creating and delivering a GIS product?***

Chapters 2 to 5 provided the theoretical basis for this study by investigating supply chains, supply chain management, GIS and the current management practices and approaches in GIS. They also investigated how supply chains and supply chain management can be applied to GIS as well as the model (SCOR model) used to map and analyse a GIS unit's supply chain and to provide input to manage the supply chain. These chapters also provided an answer to each of the following objectives:

A. *What are supply chains and supply chain management?*
B. *What is GIS and where it is applied?*
C. *How is GIS currently managed in GIS units?*
D. *Can supply chain management be linked to GIS in order to become a management tool for GIS?*

Chapter 6 introduced the GIS unit that was used to test this concept, namely ESI-GIS, and Chapter 7 described the methodology and application of supply chain and supply chain management in ESI-GIS. These two chapters provided the answer to objective E:

> *Can supply chain management be used to successfully manage the production of GIS products by a selected GIS (ESI-GIS)?*

This chapter gives a synthesis of the study, starting with the purpose of the study, and then discusses the application of supply chains and supply chain management in a GIS unit as well as the effectiveness thereof as an alternative management practice to current GIS management practices. This is followed by a summary of findings of contributions and to the disciplines of geography, GIS and logistics. The chapter starts with a discussion on complementary roles between geography and supply chains and supply chain management. It concludes that supply chain management is a better alternative management practice which will improve the efficiency and effectiveness of a GIS unit when it creates a GIS product. The chapter ends with recommendations for further research.

8.2 Geography, supply chains and supply chain management

Geography seeks answers to the question *"why are spatial distributions structured the way they are?"* (Abler, Adams and Gould, 1971). A Geographic Information System (GIS) is a powerful tool that is used to find an answer to this question (Bolstad, 2005). Geography not only tries to find an answer to the why, but also looks at the interaction between different spatial entities such as the flows of people, goods, services and information along networks between places (Abler, Adams and Gould, 1971). According to Abler, Adams and Gould (1971:195), spatial interactions are influenced by the following three factors, namely:

- *"Complementarity, depending on areal differentiation, which results in a supply at one place meeting a specific demand at another place;*
- *The intervening opportunities between places; and*
- *Transferability measured in time and money."*

Intervening opportunities are those opportunities between a place of supply and a place of need, which could be more attractive than the final destination, which results in fewer or no goods, services, etc. reaching it. Transferability looks at how easy it is to move goods, people and other commodities and services between places using various modes of transport (Abler, Adams and Gould, 1971). There several methods to analyse and model spatial interactions, such as gravity modelling, input-output modelling, origin-destination modelling, network analysis and trip generation (Abler, Adams and Gould, 1971 and Bolstad, 2005). Thus geography looks at where things are and how they interact.

With regard to supply chains, it describes the movement of goods, information and money up and down the chain between various supply chain partners (Roberts, 2003). Thus in a supply chain there are places of surplus (the supplier) and places of need (the firm). With regard to customers, the firm is then a place of surplus and the customers are a place of need. The transferability of the goods, information and money are measured in the context of supply chain management in time and cost. An example is the movement of goods from suppliers to the firm (manufacturer) using the Just-in-Time principle. Another example is the costs involved in moving goods from one place to another, which is used as a performance metric in supply chain management (Supply-Chain Council, 2001). Supply chain management is used to manage these interactions at optimal performance levels. The philosophy of supply chain management is to integrate all the linkages, for example supplier–firm–customer, into a seamless unit to maximise the benefits between supply chain partners and to optimise customer value (Hugo, Badenhorst-Weiss and van Biljon, 2004).

Based on the above, geography is involved when looking at the interaction between supply chain partners, but geography in itself needs information (goods) in the form of data to enable it to understand the spatial distribution of and interactions between entities. From a geographical as well as from a supply chain and supply chain management point of view, entities are the locations of manufacturing plants, retailers, suppliers, customers, warehouses and distribution centres. Thus the following can be deduced:

Geography and supply chains and supply chain management can complement each other as illustrated in Figure 8.1.

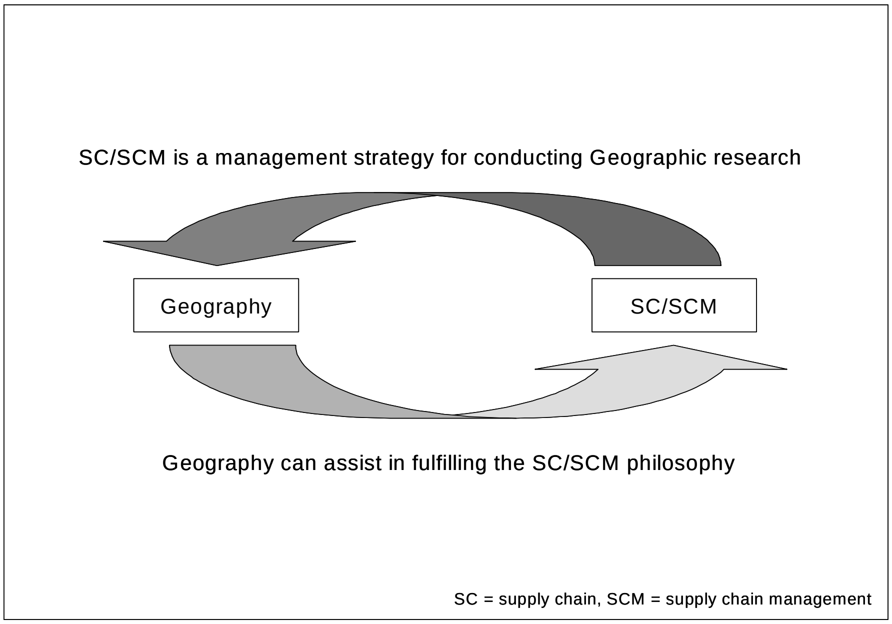

Figure 8.1: The complementarity between geography and SC/SCM

From the finding discussed above and Figure 8.1, supply chains and supply chain management can be used to identify data sources that are needed for geographic research which is done for a customer, even if the researcher is the customer himself/herself. Supply chain management is used to manage this data supply chain between the data suppliers, researcher and customer, which includes relationship management between the partners as well as quality control of the research output. On the other hand, geography can support supply chain management by researching the spatial distribution of supply chain entities and the interaction between them. The author is currently involved in a project with a building material manufacturer and supplier to establish whether his distribution centres are optimally located with regard to his customers and manufacturing plants using interaction modelling as well as modelling of the flows between the firms, suppliers, distribution centres and customers. The aim of this study is to optimise the supply chain of the building materials manufacturer.

Since GIS is a tool that can be used in geography, it can thus be surmised from Figure 8.1 that supply chains and supply chain management can be used as management tools to improve the ability of a GIS unit to create a GIS product and deliver it to a customer in the most efficient and effective manner. Bolstad

(2005:3) also indicates that the use of GIS as a tool is not restricted to geography, but is also used in various applications ranging from archaeology to zoology. In order to understand this it is necessary to clearly define the purpose of this study, which is done in the next section.

8.3 Purpose of the study

The research objective of this study as stated in Section 1.5 was to establish whether the concept of supply chains and the use of supply chain management can assist GIS units to be more efficient and effective in the use of GIS when creating and delivering a GIS product.

The above statement was made owing to the thinking in current literature on GIS management that GIS is currently managed as a holistic process, which ranges from establishing the need of a GIS in an organisation to its eventual implementation into the organisation, as well as some operational management aspects of running the GIS unit. Operations and operational management aspects do show elements of supply chains and supply chain management, but these elements are done in silo fashion as discussed in Section 4.7. Workflows are used to automate the whole or parts of the GIS product creation processes. Workflows form part of the MAKE process of the GISDataSCOR (GDS) model (for a detailed discussion on the GDS model see Section 7.4).

To fully enable supply chains and supply chain management in the creation of a GIS product by a GIS unit, it was necessary to explore in detail what the concepts of supply chains and supply chain management consist of. Chapter 2 explored these concepts, which range from logistics management to operations through to the role of information and communications technology in supply chains. From Chapter 2 it was concluded that the concept of supply chains and supply chain management is a holistic approach, albeit different from the management approach currently applied to GIS as discussed in Chapter 4. Supply chain management looks at the flow of products, information and money up and down the supply chain as well as the creation of relationships between supply chain members and the total quality control of the products created. The aim of supply chains and supply chain management is to enable supply chain members to be as efficient and effective as possible to outperform the competition (De Kok and Graves, 2003). In Section 1.4 a few definitions of a GIS were given, which indicates that a GIS unit needs to source (acquire) spatial, related non-spatial and other data, referred to as data for the purpose of this chapter, from somewhere. Once the GIS unit has the data, it transforms and manipulates the data to create a GIS product, which when completed, is used in most cases by somebody else within or outside the organisation in which the GIS unit is located. The GIS unit itself can also be a customer.

Based on the above, it was concluded that it could be possible to enable supply chains and supply chain management in a GIS unit to improve it's the unit's efficiency and effectiveness in creating GIS products and also to achieve objective A, namely "*What are supply chains and supply chain management?"*. In order to verify this conclusion, it was necessary to investigate the concept of GIS in more detail. A two-pronged approach was utilised to understand the concept of GIS, namely looking at GIS *per se* and then investigating how GIS and the creation of GIS products are currently managed as reflected in the literature.

During the investigation of GIS as discussed in Chapter 3, the definition of a GIS was established that relates to this study, namely:

> *A GIS is a computer-assisted system, combined with appropriate infrastructures, resources and management, that acquires, stores, retrieves, transforms, manipulates and displays geographical and related non-geographical data.*

It was further established that GIS evolved over the years from a tool developed in a university laboratory to a complex and sophisticated tool that is used by either a single entity or enterprise-wide by organisations (Foresman, 1998). This implicates that a GIS needs to be properly implemented and is subject to legal issues as well as various standards. The latter ensure that the GIS product that is being created by a GIS unit is of sufficiently high quality.

The definition of a GIS as given above clearly indicates that a GIS by nature has the characteristics of a supply chain, namely sourcing from suppliers (acquire), producing (stores, retrieves, transforms and manipulates) and delivering to a customer (displays). Furthermore, it was established in Chapter 2 that legal issues and standards are an integral part of a supply chain, which is managed through supply chain management with the aim that the produced product should be of sufficiently high quality when delivered to a client. It is the same in the context of GIS, as mentioned in the previous paragraph. Thus based on what was mentioned before, and the nature of GIS, GIS falls within the ambit of supply chains and these can be managed through supply chain management. Chapter 3 furthermore answered the second objective, namely *"What is GIS and where it is applied?"* satisfactorily.

In order to verify whether the concept of supply chains and supply chain management is currently being applied within the context of GIS product creation by a GIS, it was necessary to research the current management practices of GIS as given in the literature and discussed in Chapter 4. In Section 4.7 it was concluded that only elements of supply chains and supply chain management are currently being used in the management of GIS and the creation of GIS products.

Implementation management is necessary to establish a GIS in an organisation, which in turn makes the necessary resources available, namely hardware, software and human resources to create a GIS product. These resources are used when applied to supply chains and when supply chain management is used in the PLAN processes of the GDS model. Maintenance management in the GIS environment is done at two levels, namely the maintenance of the hardware and software of the GIS unit and the maintenance of the data and GIS products that are used and created by the GIS unit. Maintenance management ensures that a continuous provision of resources is available to create the various GIS products. PLAN processes in the GDS model use this information to balance the supply chain resources with the supply chain requirements.

When discussing the operational management of a GIS unit (Section 4.3.3) and the maintenance and maintenance management of the data (Section 4.3.4), it was discovered that aspects of operational and maintenance management, including customers, are discussed as disjointed elements in the whole process. Sugarbaker (1999,) however, does highlight certain supply chain elements such as order management, customer relations management and support. Operations, operational management and the maintenance of data are part of the GDS model's MAKE processes. Customer support is part of the DELIVER processes. Operational support management, which includes legal issues and compliance with standards and customer relations management, are part of the ENABLE MAKE and ENABLE DELIVER processes of the GDS model respectively. The ENABLE processes are those processes that enable the supply chain to operate. It was also discussed in Chapter 4 that workflows are used to determine the sequence and to automate or partially automate the steps involved in creating a GIS product, and it was concluded that workflows can be used as a tool in the MAKE process of the supply chain.

It can therefore be concluded from the above discussions that current management activities in GIS as given in the literature only show elements of supply chains and supply chain management. This chapter has thus realised the third objective, namely *"How is GIS currently managed in GIS units?"* Most of these management activities or processes occur in a silo fashion, and there is very little integration of the activities. Taking into account the above discussions on the elements of supply chains and supply chain management, as well as a supply chain being implicit in a GIS as given in the definition, it can be concluded that supply chains and supply chain management can be used as an alternative to the current management processes of creating a GIS product, which is the very reason for the existence of a GIS unit.

This application of supply chains and supply chain management in creating a GIS product is the purpose of this study.

8.4 Supply chains and supply chain management

In the previous section it was established that supply chains and supply chain management can be applied to the creation of GIS products. In order to fulfil the purpose of this study, it was necessary to discuss the applications of supply chains and supply chain management in detail before this concept could be tested on a GIS unit. Chapter 5 detailed this investigation using the same framework that was used in Chapter 2 to investigate the application of supply chains and supply chain management in the context of GIS when a GIS product is being created by a GIS unit.

As illustrated in Figure 8.1, supply chains and supply chain management can be used as a management tool to conduct geographic research. Since GIS is a powerful tool to conduct geographic research and is seen as a sub-discipline of geography, as well as being used in other applications such as facilities management, the creation and maintenance of core data sets and disaster and risk management, it was concluded that supply chains and supply chain management could be used in the GIS context. In order to fully apply the concept of supply chain management in the GIS context, a tool is needed to analyse a GIS unit's supply chain and to provide input for use in supply chain management.

The tool that will be used to map and analyse the supply chain and guide the supply chain management of a GIS unit was introduced in Chapter 7. This tool is the GISDataSCOR (GDS) model, which is an adapted model of the Supply-Chain Operations Reference (SCOR) model. The SCOR model was developed by the Supply-Chain Council (see Section 2.5 for a detailed discussion on the SCOR model). It was discovered, as mentioned in Section 7.3, that the standard SCOR model could not be applied in its entirety to a GIS unit and that it was necessary to adapt the model to fit into a GIS context. The essence, philosophy and approach of the adapted model are the same as those of the original SCOR model. The SCOR model was used as a guide in the discussion of the various aspects of supply chain and supply chain management as applied to a GIS unit, which range from logistics management, materials management, operations to global GIS supply chains as illustrated by the QuickBird satellite image example in Section 5.8.

An important contribution in Chapter 7 is the introduction of a fourth MAKE process, namely Maintain-to-Stock (M4) in the GDS model. The Maintain-to-

Stock (M4) process looks at the maintenance of existing (stocked) GIS products such as digital 1:50 000 topographic maps. From Chapter 5 it can definitely be concluded that the concepts of supply chains and the application of supply chain management can be applied within the GIS environment.

Chapter 5 clearly realised the fourth objective, namely *“Can supply chain management be linked to GIS in order to become a management tool for GIS?”* It has thus been established that supply chains and supply chain management can be applied in the GIS environment when a GIS product is being created, and that a model, the GDS model, is available to model and analyse the supply chain to provide input for managing it. To test this, it was necessary to apply the process to a GIS unit. The GIS unit used in the study was ESI-GIS, a GIS unit in Eskom which provides GIS products to the various departments and regional offices of Eskom.

Chapter 7 discusses the application of supply chains and supply chain management to the creation of GIS products by ESI-GIS. As mentioned in Section 7.1, two studies were done. The first analysis of ESI-GIS’s supply chain was done using the standard SCOR model as provided by the Supply-Chain Council to provide input to enable ESI-GIS to apply supply chain management to improve the supply chain. From the first study, it was discovered that the standard SCOR model needs to be adjusted for proper use in the GIS context and it was applied in the second study to determine the impact of the first study on the supply chain of ESI-GIS and provide new inputs for supply chain management.

The methodology of both the studies is based on the methodology described by Bolstorff and Rosenbaum (2003) and consists of the following phases:

- The business context of a GIS unit.
- Performance and benchmarking using the SCORcard.
- Mapping the AS IS material flow.

- Doing the disconnect and opportunity analysis for each identified unique problem statement based on the disconnect analysis.
- Identifying areas of improvement by mapping and analysing the GIS unit's AS IS supply chain processes at GDS Level 3 as well as mapping the TO BE processes at GDS Level 3.
- Recommendations and implementations.

The advantage of using the methodology as described by Bolstorff and Rosenbaum (2003) is that it gives a structured approach in using the SCOR model, and in this study it gave the structured approach of using the GDS model. The SCOR manual as developed by the Supply-Chain Council (2001) also gives an approach to the use of the SCOR model, but it is not as clearly outlined as in Bolstorff and Rosenbaum (2003).

The business context gives the context in which the GIS unit operates - its finances, its strengths, weaknesses, opportunities and threats as well as its reason for existence. It also indicates which GIS product range's supply chain will be analysed using GDS. ESI-GIS's business context is given in Chapter 5. The advantage of starting with the business context is that it creates a link between the operations of the GIS unit and the business goals of the unit and/or the organisation in which the unit is located, and also provides a basis for improved supply chain performance over the long term (Bolstorff and Rosenbaum, 2003). Another advantage of establishing the business context first is that it provides an understanding of the GIS unit for an outside person conducting the analysis and reminds the staff of the GIS unit of the reason why the unit exists.

The GDS Level 1 supply chain performance is reflected in the SCORcard, which looks at the delivery performance of the GIS unit, its perfect order fulfilment and how long in days the GIS unit takes to fulfil its orders, as well as how quickly it is able to react to changes within the supply chain.

The next few metrics look at the cost of the supply chain to the GIS units, namely cost of goods sold, which includes material (spatial, related non-spatial and other data) and labour costs; supply chain management costs which include acquisition and customer service costs; sales; and general and administrative costs that are needed to support the GIS unit to enable it to manage the supply chain and to manufacture the GIS products. Return costs looks at the costs involved to deal with faulty material from the suppliers and faulty GIS products delivered to customers.

Cash-to-cash cycle time looks at how many days the money invested by the GIS unit is tied up in the production process before it is recovered through sales. Inventory days of supply looks at how long the money that has been invested in materials is tied up before it is recovered through the sale of GIS products. Asset turns gives an indication of the ability of the GIS unit to make money by determining the amount of money the GIS unit makes for every rand the GIS unit invests in assets. These metrics look at how efficiently the GIS unit manages its supply chain assets.

The next set of metrics looks at the profitability of the GIS unit. The first metric is the gross margin, which is calculated by subtracting the cost of goods sold from the revenue. The second metric is the operating margin, which is calculated by subtracting the cost of goods sold and the sales and general and administration costs from the revenue. The last metric is net income, which is determined by subtracting all the costs and taxes involved from the revenue that the GIS unit generated for a particular financial year. The last metric of the SCORcard is the return on assets, which is calculated by dividing the net income by the total net assets. This metric determines the GIS unit's effectiveness of return. Return on assets is an indication of how well a GIS unit's assets can create income (Supply-Chain Council, 2001).

All the above metrics are also used to compare the GIS unit's performance against the performance of its competing GIS units if the data are available, which will indicate to the GIS where to improve its performance using supply chain management in order to achieve or retain a competitive advantage.

Unfortunately there are currently no benchmarking data readily available from competing GIS units with which to compare ESI-GIS's performance to its competitors'. Although it would have been to ESI-GIS's advantage if they were available, the results of the metrics did give a good understanding of how ESI-GIS's supply chain is performing. In the second study a comparison was given (Table 7.24) with regard to ESI-GIS's performance against its competitors', namely whether ESI-GIS was on a par (parity) or had an advantage over its competitors or was superior to its competition. However this is based on the subjective perception of ESI-GIS's manager, based on his long experience of GIS in South Africa, and should be treated with caution. It is recommended that a data repository should be established in which the performance metrics of various GIS units can be stored which is updated on a regular basis and made available for benchmarking purposes.

The third phase analyses the GIS unit's AS IS supply chain at GDS Level 2 by mapping its material flows (spatial, related non-spatial and other data as well as GIS products) from the various suppliers to the GIS unit and from the GIS unit to its customers. The GDS Level 2 process categories such as S1 (Source stocked products), M4 (Maintain-to-Stock) and D1 (Deliver stocked product) are used to map the flows on a map and as a flow diagram. The importance of the GDS Level 2 as well as the SCOR Level 2 flow diagram is that at this level the supply chain is defined, which guides the GDS or SCOR Level 3 analysis. An example is if the GIS unit only creates stocked GIS products, and the M2 (Make-to-Order), M3 (Engineer-to-Order), D2 (Deliver Make-to-Order product) and D3 (Deliver Engineer-to-Order product) process categories are excluded from the analysis.

The material flow performance is determined from these material flow maps and flow diagrams using material flow performance metrics such as transportation costs, inventory and returns (see Table 7.7). Although the methodology makes provision for the material flow performance, it was not done for this study since not all the data were available. The Cost of Goods Sold (COGS) and the delivery performance were captured on the SCORcard. It is recommended that research be done into the relevance of these metrics, and that new metrics be developed if applicable as well as methodologies to collect the necessary information to populate the table. It was concluded that it would have been advantageous to have the information, although it was not critical to this analysis, since some of these metrics are revisited during the GDS Level 3 analysis, which gives an indication of the performance of the material flows to and from ESI-GIS.

The fourth phase is the disconnect and opportunity analysis phase, using the SCORcard and the GDS Level 2 AS IS supply chain as guides. The different disconnects are determined through a participatory process which involves all the staff members of the GIS unit and are reflected as unique problem statements in cause-and-effect diagrams. The advantage of involving the staff members of ESI-GIS was that it provided an opportunity for them to identify various problems they experience when they are creating GIS products. To prevent this procedure from being dominated by strong personalities and to remove any fear of retribution or victimisation, the staff members wrote their various disconnects for each management process on pieces of paper provided by the researcher. These were then grouped into unique problem statements. These unique problem statements were then turned into various opportunities, the financial impact of which could be determined using the SCORcard values as input values. An example of an opportunity is the reduction in labour costs by improving the skill of the staff members in the GIS unit. These opportunities as defined by each unique problem statement are linked to various GDS Level 2 process categories to indicate where in the supply chain these opportunities will have an impact.

The next phase is the detailed analysis of the GIS unit's AS IS supply chains at GDS Level 3 process element level using the GDS model manual and the workbooks as discussed in Section 7.2.5.2. As mentioned above, the GDS Level 3 process element supply chain analysis is guided by the GDS Level 2 process category AS IS supply chain, since a GIS unit may not use all the process categories to define its supply chain. Thus when doing the GDS Level 3 process element analysis of the supply chain, all the process elements related to the excluded process categories are excluded from the analysis.

The GDS Level 3 analysis is divided into two sub-phases, namely mapping the GDS Level 3 AS IS supply chain using the SWIM diagram with the different functions or departments of the GIS unit depicted as swimming lanes. The appropriate GDS Level 2 process category and GDS Level 3 process element is each placed in a swimming lane and the information and material flows are shown as links between each process element. The second sub-phase is the use of the different workbooks to analyse each process element and capture information on its performance metrics, current practices, business rules, execution processes, the different disconnects experienced when executing the process element and possible future improvement of current practices. The advantage of using the workbooks is that it provides a structure in which each GDS Level 3 process element can be analysed and also provides a method to archive the relevant information for later use.

The information gathered on the performance metrics is analysed to indicate the performance of the supply chain for the various GDS Level 3 process elements using the five performances attributes, namely:

- Reliability
- Responsiveness
- Flexibility
- Cost
- Assets.

The aim is to improve the performance attributes by addressing the various disconnects linked to the process elements.

The various disconnects identified at each process element are linked back to the various causes and sub-causes as presented in the cause-and-effect diagram of each unique problem statement.

Using the performance data and the different disconnects identified as well as the information from all the other phases, a TO BE GDS Level 3 process element level supply chain is mapped by adding or removing swimming lanes, i.e. functions or departments, to improve the efficiency and effectiveness of the supply chain. A unique identifier is given to each identified disconnect, which is then linked to the relevant process element in the TO BE GDS Level 3 supply chain.

From the GDS Level 3 process element analysis various disconnects are identified and linked back to the unique problem statements that are needed to be solved through supply chain management in order to improve the supply chain. These enable the GIS unit to manage the improvement optimally - the different disconnects are prioritised, ranging from those disconnects that have the biggest impact on the supply chain to those having the smallest impact when they are solved. The information captured in the workbooks on practices, business rules and processes to execute the process element and the GDS model manual, which includes best practices and features, is used as a tool to solve the identified disconnects.

When mapping the GDS Level 3 AS IS and the TO BE supply chains, the various enabling processes are not mapped so as not to over-complicate the mapped supply chain. When improving the supply chain using the TO BE supply chain at the GDS Level 3 process element level, the enabling processes are identified at each process element using either the GDS model manual or the workbooks where the enabling process is indicated in the input and output fields of the table given for each process element. These enabling processes are then used when improving the supply chain at the relevant process element as described above. The metrics and best practices at GDS Level 3 were determined from inputs by people working in GIS, but were mainly based on the researcher’s own involvement in GIS. It is therefore recommended that each GDS Level 3 process element should be investigated in detail to improve the metrics, and that other relevant best practices to execute these process elements should be established. As with the materials flow performance analysis, some of the metrics in the GDS Level 3 process elements could not be determined owing to the lack of information. GDS Level 3 AS IS and TO BE provided valuable insight into the performance of ESI-GIS’s supply chain, where the problems are in the supply chain. These problems need to be addressed using supply chain management, and a clear understanding must be provided of where in the supply chain each line function functions. The GDS Level 3 supply chain map makes the supply chain visible to all the functions, which is necessary for improved supply chain performance (Roberts, 2003).

The last phase of the methodology is to present the results and set up an improvement plan in which supply chain management will be used to improve the supply chain based on the above results.

The above steps and the various metrics that were used to analyse the supply chain and the performance of the supply chain of ESI-GIS have not been tested in detail to develop controls, which are used to ascertain whether the value makes sense or not. However, these steps and metrics were based on those that were developed for use in other industries (Supply-Chain Council, 2001 and Bolstorff and Rosenbaum, 2003). Although the GDS model, as an adapted Supply-Chain Operations Reference (SCOR) model, is in its first version, it did provide sufficient insight into a GIS unit's supply chain to provide the necessary information needed to guide the improvement of the GIS unit's supply chain by using supply chain management when creating GIS products, thus making the creation and delivery of a GIS product using GIS more efficient and effective and answered the last objective (*Can supply chain management be used to successfully manage the production of GIS products by a selected GIS (ESI-GIS)?*).

It is recommended that the various performance metrics as given in the five performance attributes, and the various best practices and features given in each process category and process element should be improved and tested through further research, and that this should lay the foundation for such research.

8.5 Summary of contributions and findings

This study investigated the use of supply chains and supply chain management to improve the efficiency and the effectiveness of a GIS unit when creating and delivering a GIS product to its customers, which has contributed new knowledge with regard to the use of supply chains and supply chain management outside the existing manufacturing, service and retail industry as well as to geographic information systems management. By realising all five of the objectives it can thus be concluded that the research aim as given below has been suitably achieved:

> ***Can the establishment of supply chains and the utilisation of supply chain management assist a GIS unit to be more efficient and effective in the use of GIS when creating and delivering a GIS product?***

To briefly illustrate the realisation of the above research aim, ESI-GIS's supply chain performance is summarised in Table 8.1:

Table 8.1: ESI-GIS's supply chain performance

Performance Attribute/Category	**Level 1 Performance Metric**	**2004/2005 Study**	**2006/2007 Study**
Supply Chain Delivery Reliability	Delivery Performance	77%	73%
	Perfect Order Fulfilment	43%	68%
Supply Chain Responsiveness	Order Fulfilment Lead Time (days)	3 days (64% of the work) More than 3 days (16% of the work) 1 year (20% of the work)	120 days (measured differently for this study)
Supply Chain Flexibility	Supply Chain Response Time (days)	(n/a)	43 (for ad hoc projects it is 3 days)
Supply Chain Costs	Costs of Goods (Costs of goods sold – COGS)	50%	87%
	Total Supply Chain Management Costs	26%	11%
	Sales, General and Administration Costs (SG&A Costs)	24%	2%

Performance Attribute/Category	Level 1 Performance Metric	2004/2005 Study	2006/2007 Study
	Returns Processing Costs	Not measured as a separate entity, part of COGS	Not measured as a separate entity, part of COGS
Supply Chain Asset Management Efficiency	Cash-to-Cash Cycle Time (days)	n/a	1 516 (Assumption 1)
		n/a	161 (Assumption 2)
	Inventory Days of Supply (days)	n/a	1 389 (Assumption 1)
		n/a	34 (Assumption 2)
	Asset turns	n/a	9.89
Profitability	Gross Margin	50%	-17.88%
	Operating Income (Margin)	23%	-31.98%
	Net Income (Net Operating Income)	Taxes not available	Taxes not available
Effectiveness of Return	Return on Assets	Not available	Not available

Assumption 1: The data that are estimated at R60 000 000.00 (de la Rey, 2007) are only used once, so the Cash-to-Cash cycle time that measures the number of days that cash is tied up as working capital (Supply-Chain Council, 2001) will be 1 516 days.

Assumption 2: Most GIS units re-use the data regularly. The average re-use of the data by ESI-GIS is 41 times (de la Rey, 2007), thus the data become “cheaper” the more they are used, which equates to R1 463 414.63: this gives a Cash-to-Cash cycle time of 161 days.

From Table 8.1, the main conclusion that can be drawn is that after the first study (the 2004/5 study) ESI-GIS did apply the results in the form of supply chain management and improved the performance of its supply chain. It was also able to provide information for four performance metrics in the 2006/7 study as shown in Table 8.1, with supply chain asset management efficiency being the most important contribution. The negative values in the profitability of ESI-GIS are due to non-payment of GIS products delivered to customers. Another finding is that after the first study, ESI-GIS provided training for staff on GIS skills and project management in order to improve project management (including the planning of projects), GIS product creation and customer relationships. This resulted in a better understanding of certain problems in the supply chain such as those experienced in planning; sourcing data from suppliers; the creation of GIS products; the delivery of the GIS product to the customers and the customers themselves (see Table 7.25) in comparison to the same exercise done in the first study (see Table 7.16). This is encouraging since it shows that the more ESI-GIS uses the concepts of supply chains and supply chain management, the more the unit is able to identify problems in the supply chain in a structured manner and react accordingly, using supply chain management to improve the supply chain. This improved sensitivity led to the identification of seven problems (disconnects) as shown in Table 8.2, which if solved, will have an 80% impact on the supply chain. These seven problems would not have been identified if ESI-GIS had not used the concept of supply chains and supply chain management.

Table 8.2: The identified disconnects that have an 80% impact

Disconnect	**Process element that is affected by the disconnect**
Non-compliance with data standards (11)	M1.3, M2.3, M3.4, M4.3
Faulty data from suppliers (7)	S1.2, S1.3
Non-adherence to regulatory requirements (8)	S1.2, S1.3
Poor data quality (10)	M1.1, M3.2, M4.1
Lack of advanced GIS skills (18)	M1.3, M2.3, M3.2, M3.4, M4.3
Do not know what data are available (4)	M1.2, M1.3, M2.2, M3.3, M3.4, M4.2, M4.3
ISO processes not updated (9)	M1.3, M2.3, M3.4, M4.3

The numbers in brackets behind each disconnect indicates in Figure 8.2 where in the GDS Level 3 TO BE supply chain these seven problems have an impact. The other numbers in Figure 8.2 are linked to those identified problems that have either a 15% or 5% impact on the supply chain as given in Section 7.4.

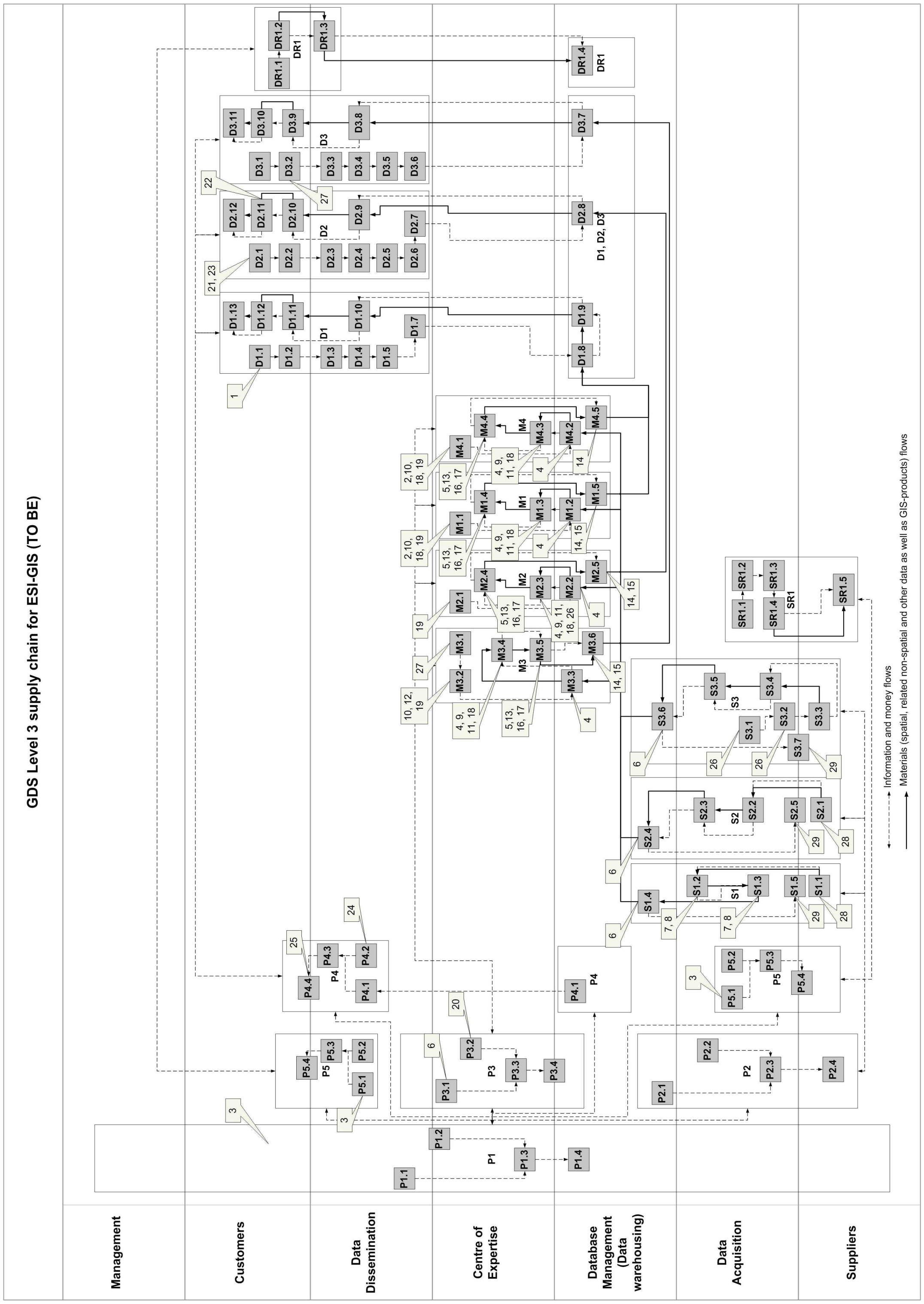

Figure 8.2: ESI-GIS TO BE GDS Level 3 supply chain with disconnects

Although it takes some effort to model and analyse a GIS unit's supply chain using the GDS model to provide input for supply chain management as illustrated in Chapter 7, the attractiveness of this approach is that the results (findings) can be summarised in two tables (Table 8.1 and 8.2) and in one figure (Figure 8.2), which can be used by the staff to plan and improve their supply chain. It was also discovered during the second study that the modelling and analysis of ESI-GIS's supply chain was easier since the staff had a better understanding of the concepts of supply chains and supply chain management and could also build on the information available form the first study. Based on the above, the conclusion can be drawn that applying the concept of supply chains and the use of supply chain management can assist GIS units to be more efficient and effective in the use of GIS when creating and delivering a GIS product, and that the purpose of this study has been fulfilled.

Chapter 4 investigated various management strategies that are currently employed in managing GIS. As indicated in Chapter 4 and Section 8.3, there is currently some form of operational and maintenance management in GIS units to manage their day-to-day business. This management strategy was also employed by ESI-GIS. ESI-GIS had a project management system to manage the various projects and some form of customer relations management. Their procurement was haphazard, and since they did not keep proper control of their inventory, they purchased duplicate data sets (de la Rey, 2005 and 2007). There was no integration between the various functions within the GIS unit, which led to operational inefficiency when the GIS unit created their various GIS products. By applying the concepts of supply chains and supply chain management, and through the modelling and analysis done using the SCOR model and the subsequent improved SCOR model, the GISDataSCOR (GDS) model, ESI-GIS was able to view the whole chain involved in the production of their GIS products. ESI-GIS also realised that to be more effective and efficient they needed to manage the whole chain. Management of the whole chain can only be achieved through supply chain management. De la Rey (2005) indicated after the first study that the identified problems within ESI-GIS could be turned into opportunities to improve the overall performance of the GIS unit. The use of the SCOR and the GDS model enabled ESI-GIS to clearly define their supply chain problems and to improve the supply chain by addressing these problems using supply chain management. The other advantage of using supply chains and supply chain management is the total quality management aspect of supply chain management, which ensures that the GIS product delivered to the customer is of high quality. Thus supply chains and supply chain management provide a holistic management methodology to manage an operational GIS unit, which is not possible with the current management methodologies in practice, as was demonstrated in Chapter 7 and discussed above.

The main contributions with regard to this study can be summarised as follows:

- Supply chains and supply chain management can be successfully applied to a GIS unit to manage its operations as demonstrated in Sections 7.3 and 7.5 and discussed in Section 8.3. This alternative management methodology contributes to the pool of knowledge of various existing management methodologies of managing GIS as discussed in Chapter 4. Since data play an important role in any geographical study, ranging from urban geography, to geomorphology to environmental impact studies, the principles of supply chains and supply chain management can be used to manage the data collection process. Thus a new method of data collection, planning and management is provided to the discipline of geography as a whole and not to GIS alone. Supply chains and supply chain management can also be used to measure the performance of the various data collections in the various sub-disciplines of geography to provide improved data collection in the future.
- To enable a GIS unit to analyse its supply chain, a model was developed based on the Supply-Chain Operations Reference (SCOR) model as developed by the Supply-Chain Council, namely the GISDataSCOR (GDS) model, as well as the methodology and the five workbooks as tools to assist in the analysis.
- The study provided a mechanism for a GIS unit to understand its operations with regard to planning, sourcing from suppliers, the creation of

a GIS product and the delivery of the GIS product to its customers, and how to deal with faulty data and GIS products.

- The study provided a mechanism for a GIS unit to determine its supply chain performance, the recording of current practices, possible improvements, current business rules, disconnects (problems) and the processes involved in executing a specific element of the supply chain. These aspects form the basis for a GIS unit to improve its supply chain using supply chain management.
- The methodology provides the means with which to prioritise the different identified disconnects, i.e. which disconnect must be solved first.
- A new process category has been added to the GDS model, namely M4 (Maintain-to-Stock), which looks at the maintenance of existing data, be it spatial or non-spatial data.
- The study also provides the mechanisms by which a GIS unit can carry out its quality management using applicable standards, and meet the legislative and other regulatory requirements regarding spatial information through the use of the enabling processes as discussed in Section 5.2 and
- Supply chains and supply chain management are currently utilised in the manufacturing industry and to some extent in the service industry, which involves the creation and movement of physical entities such as motor vehicles, pharmaceuticals and fast-moving consumer goods. The application of supply chains and supply chain management in the context of GIS has enabled new concepts for supply chains and supply chain management to be developed, namely:

    - Raw materials: different spatial, related non-spatial and other data from suppliers.
    - A warehouse now becomes a data warehouse.
    - A GIS product (map) is a commodity created from sourced raw materials.
    - Inventory: available data layers in a data warehouse or other storage devices.

- Distribution centre: an Internet or FTP site from which GIS products can be downloaded. An enterprise-wide data server is also a distribution centre.
- Transport: data via Internet, Intranet, WAN/LAN or on CD-ROM, DVD or RHD which are transported personally or via a courier company acting as a third party logistics (3PL) provider for the GIS unit.

- The application of supply chains and supply chain management in the GIS context expanded the application of supply chains and supply chain management especially into the information (data) domain.
- The GDS model manual and the workbooks and methodology developed can be utilised as a paper-based exercise, thus eliminating the purchase of sophisticated software. It is, however, recommended that commercial off-the-shelf office software such as Microsoft Office, Microsoft Visio or similar open source office software be used together with the paper-based analysis.
- It provides an opportunity for a GIS unit to benchmark itself against its competitors.
- The study has laid the foundation for a new sub-discipline in logistics, namely data logistics.

8.6 Conclusions

The purpose of this study as outlined in Chapter 1 was to provide a comprehensive management process to manage an operational GIS unit as an alternative to what was currently described in literature, namely the use of supply chains and supply chain management to improve the efficiency and effectiveness of a GIS unit when it creates and delivers a GIS product. From the application of supply chains and supply chain management to the creation of GIS products by a GIS unit as described in Chapter 7 as well as in the above sections of this chapter, it is concluded that the use of supply chains and supply chain management does provide an improved management alternative to current management practices in GIS and also improves the efficiency and effectiveness of a GIS unit when it creates a GIS product.

Although the application of supply chains and supply chain management using the GISDataSCOR (GDS) model to model and analyse a GIS unit's supply chain is not perfect, the study laid the foundation for further improvements with regard to the GDS model itself, the methodology to carry out the analysis and the workbooks that were developed to do the GDS Level 3 process element level supply chain analysis.

The introduction of supply chains and supply chain management in managing a GIS unit provided a mechanism to integrate the various loosely tied aspects within a GIS unit that are currently managed individually. Supply chains and supply chain management enable a GIS unit to identify the weak links in the supply chain which are then managed accordingly as shown in Chapter 7.

It is concluded that this study has made a significant contribution to the discipline of geography and to GIS in particular, as well as to logistics, in particular supply chains and supply chain management with regard to a new approach to managing an operational GIS.

The following is a list, albeit incomplete, of recommendations for further research that emanated from this study:

- Establish benchmarks based on information gathered from various GIS units to measure the performance of a GIS unit against these benchmarks.
- Research and refine each GDS Level 3 process element.
- Refine and add best practices for each GDS Level 3 process element.
- Refine and add features of each best practice that have been identified for each GDS Level 3 process element.
- Determine and/or define performance metrics for a GIS supply chain for each GDS level.

- Expand GDS to incorporate any type of data creation ranging from a single unit to enterprise-wide applications.
- Develop data logistics as a sub-discipline of logistics.
- Improve the methodology used to analyse the supply chain of a GIS unit.
- Improve the workbook concept to analyse the supply chain at GDS Level 3 process element level.

It is recommended that anyone who wishes to apply supply chains and supply chain management to manage an operational GIS unit to make it more effective and efficient in its GIS product production by improving the supply chain, should attend at least one course on supply chain management to acquire a basic understanding of supply chains and supply chain management.

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Appendix A: ISO standards for GIS

ISO 6709 Standard representation of latitude, longitude and altitude for geographic point locations

ISO 19101 Geographic information – Reference model

ISO 19101-2 Geographic information – Reference model – Part 2: Imagery

ISO 19103 Geographic information – Conceptual schema language

ISO 19104 Geographic information – Terminology

ISO 19105 Geographic information – Conformance and testing

ISO 19106 Geographic information – Profiles

ISO 19107 Geographic information – Spatial schema

ISO 19108 Geographic information – Temporal schema

ISO 19109 Geographic information – Rules for application schema

ISO 19110 Geographic information – Methodology for feature cataloguing

ISO 19111 Geographic information – Spatial referencing by coordinates

ISO 19112 Geographic information – Spatial referencing by geographic identifiers

ISO 19113 Geographic information – Quality principle

ISO 19114 Geographic information – Quality evaluation procedures

ISO 19115 Geographic information – Metadata

ISO 19115-2 Geographic information – Metadata – Part 2: Extensions for imagery and gridded data

ISO 19116 Geographic information – Positioning services

ISO 19117 Geographic information – Portrayal

ISO 19118 Geographic information – Encoding

ISO 19119 Geographic information – Services

ISO 19120 Geographic information – Functional standards

ISO 19121 Geographic information – Imagery and gridded data

ISO 19122 Geographic information – Qualifications and certification of personnel

ISO 19123 Geographic information – Schema for coverage geometry and functions

ISO 19124 Geographic information – Imagery and gridded data components

ISO 19125-1 Geographic information – Simple feature access – Part 1: Common architecture

ISO 19125-2 Geographic information – Simple feature access – Part 2: SQL option

ISO 19125-3 Geographic information – Simple feature access – Part 3: COM/OLE option

ISO 19126 Geographic information – Profile – FACC data dictionary

ISO 19127 Geographic information – Geodetic codes and parameters

ISO 19128 Geographic information – Web Map server interface

ISO 19129 Geographic information – Imagery, gridded and coverage data framework

ISO 19130 Geographic information – Sensor and data models for imagery and gridded data

ISO 19131 Geographic information – Data product specifications

ISO 19132 Geographic information – Location-based services – Reference model

ISO 19133 Geographic information – Location-based services – Tracking and navigation

ISO 19134 Geographic information – Location-based services – Multimodal routing and navigation

ISO 19135 Geographic information – Procedures for registration of geographical information items

ISO 19136 Geographic information – Geography markup language

ISO 19137 Geographic information – Generally used profiles of the spatial schema and of similar important other schemas

ISO 19138 Geographic information – Data quality measures

ISO 19139 Geographic information – Metadata – XML schema implementation

ISO 19140 Geographic information – Technical amendment to the ISO 191** Geographic information series of standards for harmonization and enhancements

Appendix B: *MAPS geosystems*' QuickBird satellite image order form

From:

Name: ____________________________

Company: ____________________________

Address: ____________________________

____

Postal Code: ____________________________

Country: ____________________________

Tel : ____________________________

Fax: ____________________________

Email: ____________________________

Order Date __________

To:

MAPS geosystems
Satellite Imagery Department
P.O. Box 5232, Sharjah
United Arab Emirates
Tel: + 971 6 5725411
Fax: + 971 6 5724057
http://www.maps-geosystems.com
quickbird@maps-geosystems.com

Please fill in and return. Do not hesitate to contact a member of our team if you have queries regarding the products/parameters.

QuickBird Order Request Form

Please specify the type of application this imagery will be used for:

Please Select If other, Please specify:

End User Organisation (if different from above)

Name:		P.O. Box:	
Company:		Tel :	
Address:			
Postal Code:		Fax:	
Country		Email:	

Order type

☐ Image Library (Archive) — Select Catalogue IDs:

☐ New Acquisition — Tasking Type: Please select

Latest acceptable end collection date:

Subscription order (multiple collects over same area)

☐ Yes ☐ No

☐ Unknown

Product Parameters

Product type (see the last page for detailed description)	**Product Option** (see the last page for detailed description)
Please Select	Please Select

Licensing

Specify License Requirements: Please Select

Geographic Area/Areas of Interest

Description:	

For multiple entries, please press Enter key after each entry

Area Name(s)	Size(s) km^2	Country (Countries)	Acceptable Dates for Images	
			From:	To:

Geographic coordinates

All information must be provided in WGS84 Geographic Lat/Long for

any option below

☐ **Option 1:** corner coordinates

(For multiple entries, please press the Enter key after each entry)

Name	**Upper Left** Longitude Latitude	**Upper Right** Longitude Latitude	**Lower Right** Longitude Latitude	**Lower Left** Longitude Latitude

☐ **Option 2:** Centre point with either height/width or radius

(For multiple entries, please press the Enter key after each entry)

Name	Longitude Latitude	Height (Km)	Width (Km)	Radius (Km)

☐ **Option 3:** attach an Excel Sheet or Word Document using the order described in Option 1 and/or Option 2

☐ **Option 4:** attach an ASCII text, SHP, DWG or DGN

Deliverables (specifications of the final product)

Bit Depth:	Please select	Projection:	
Tiling:	Please select	Zone(s):	
File Format:	Please select If Other, Please specify:	Spheroid : Datum:	

Special Requirements, if any:

Additional Comments

Product Types

Basic	Radiometric and sensor corrections
Standard	Basic + Geometric correction and projection to UTM or geographic Lat/Long
Enhanced Standard	Standard + Warping to client-supplied base map, image enhancement and mosaicking
Orthorectified	Basic + Orthorectification based on client-supplied control & DTM, image

	enhancement and mosaicking
Product Options	
Non-Pansharpened Imagery – (NP)	See the products marked as (NP) in tables below
Pansharpened Imagery – (PS)	High-resolution PanImagery fused with the multispectral imagery. See the products marked as (PS) in tables below

Product Type		**Basic ***	**Standard**	**Enhanced Standard**	**Orthorectified**
Product Option		**Pixel Resolution by Product Type**			
		(As Collected)	*(Customer Selected)*	*(Customer Selected)*	*(Customer Selected)*
(NP) Panchromatic /Black & White 450-900 nm		61 to 72 cm	60 or 70 cm	60 or 70 cm	60 or 70 cm
(NP) Multispectral Blue /Green/ Red / NIR		2.44 to 2.88 m	2.4 or 2.8 m	2.4 or 2.8 m	2.4 or 2.8 m
(NP) Bundle Panchromatic & Multispectral		as above	as above	as above	as above
(PS) Natural Colour Blue /Green/ Red		NA	60 or 70 cm	60 or 70 cm	60 or 70 cm
(PS) Colour Infrared Green /Red /NIR		NA	60 or 70 cm	60 or 70 cm	60 or 70 cm
(PS) Bundle Blue / Green / Red / NIR		NA	60 or 70 cm	60 or 70 cm	60 or 70 cm
Physical Characteristics					
Pricing basis		Scene	Area based	Area based	Area based
Min order size	New Acquisition	1 scene	64 km^2	64 km^2	64 km^2
	Archive	1 scene	25 km^2	25 km^2	25 km^2
Product framing/ Final physical structure		Scene-based / Scene	Area-based / Black-fill to a MBR surrounding the ordered image pixels		
Absolute geolocation accuracy		Supplied ISD allows for processing to 23 m CE 90%, excluding terrain displacement	23 m CE 90%, excluding terrain distortion	2 m-20 m CE 90 %, varies according to control data and terrain displacement	2 m-20 m CE 90%, varies according to control data and terrain model
Product Parameters					
Number of bits/pixel deliverable image		8-bit or 16-bit		8-bit	

Projection options	N/A	Customer specified	
Elevation correction	N/A	Coarse elevation	Fine elevation correction (depending on DTM available)
Image data format options	TIFF; GeoTIFF 1.0		
Media	CD; DVD; Hardcopy / Plot / Poster		

* Basic product can be available also clipped to the Area of Interest for all Product Options (NP) & (PS)

Please contact our sales representative to check for availability